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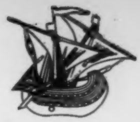

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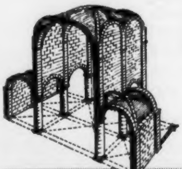

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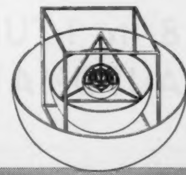

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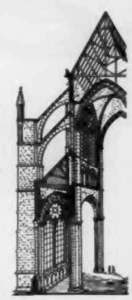

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Fare Enough

May a government scientist who is invited to attend a scientific program of public interest accept travel and related expenses from a private nonprofit organization? We are assuming that participation in the program by the government scientist will contribute to his own scientific welfare, to that of his department, and to that of the other participants. We also assume that the program is taking place during the scientist's working months. Because of decisions by the General Accounting Office which were based on a conflict of interest law put on the books in 1948, the Government's answer until recently was no. Exceptions occurred only when there was specific legislative authority for a particular department. But, now, thanks in good part to efforts by the American Geological Institute, the answer is yes. Section 19 of the Government Employees Training Act, which the President recently signed into law, provides exemptions for scientists from the 1948 law. In fact, appropriate exemptions are provided for all federal employees.

An experience in 1957 by two scientists in the U.S. Geological Survey illustrates some of the undesirable consequences of the decisions based on the earlier law by the General Accounting Office. The scientists were invited to participate in the Distinguished Lecture Tour of the American Association of Petroleum Geologists. In the course of about a month, the tour would give them the opprotnuity to exchange ideas in many parts of the country with members of interested affiliated societies and universities. The scientists were to be reimbursed for their travel expenses by the various groups that benefited from the tour. But, as a result of the decisions, one of the scientists was unable to go, while the other did so but at personal sacrifice, since he went on leave in order to be able to accept travel expenses.

The people in the General Accounting Office, however, are not the villains of the piece. As a matter of fact, there are no villains, only a certain amount of misunderstanding. The General Accounting Office people held that, under the law, their decisions were the only ones possible. If private organizations were to be permitted to pick up the tab for government scientists, they said, then corrective legislation was required. In testimony before the House Committee on Post Office and Civil Service, Ralph E. Ramsey, associate general counsel of the General Accounting Office, brought the need for this legislation to the attention of Congress. He said of his office, ". . . we would be inclined to agree that the nonprofit scientific organization which asks for the attendance of a known authority in the Government to speak to the organization should be allowed, if it wishes, to help pay his travel expenses. . . ."

Bringing the provisions of the Government Employees Training Act down to cases poses several problems that still must be worked out. The act says that payments may be made "to the extent authorized by regulation of the President." The Bureau of Programs and Standards of the Civil Service Commission is now doing staff work on these regulations. One problem the bureau faces is the situation in which modest Government funds and more generous amounts from private sources may both be available for the same trip. May the latter be used to supplement the former? A second problem is to find some formula for distinguishing between those organizations from which it is proper to accept expenses and those from which it is not. We should not be very enthusiastic about government workers' accepting funds from a foundation, however disinterested, set up by a firm that advertised a product capable of growing hair on a golf ball, especially if the funds were earmarked for personnel in the Food and Drug Administration.—J.T.

The place of the Particle Accelerator in Basic Research...

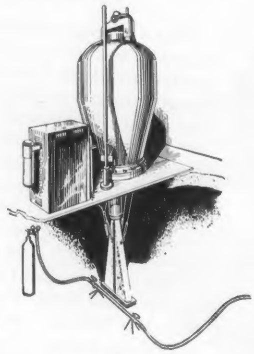
Radiation Effects in the Gaseous Phase — IX

Widespread study of the effects produced in organic and inorganic gases by high-energy particle bombardment is providing a better understanding of reaction kinetics, revealing new methods for chemical synthesis, and contributing to the new field of missile technology.

Organic Research

Complex organic molecules have been irradiated at low pressures to determine the number of dissociations per unit-energy input and to measure the lifetime of the resultant ions and free radicals. From such information, one can estimate the most probable location of the dissociation in long-chain hydrocarbons. Locating specific reactive groups at the ends of these chains permits the study of energy transfer along the chain. There is some evidence that random interactions will migrate to a weak molecular bond where chemical reaction occurs. Studies comparing ionic and free-radical mechanisms for energy transfer show that the ionic lifetimes are surprisingly long.

In addition to the gaseous phase alone, heterogeneous systems of gases or liquids and solids have been studied in relation to the catalysis of organic reactions. In such systems, these reactions occur under conditions where the reactive component is highly dispersed on a mineral support. It is believed that the products of the radiolysis of hydrocarbons may be changed under such conditions and the studies are bringing to light new methods of chemical synthesis.



Inorganic Studies

In the inorganic field, studies of plasmas and gaseous reactions have been carried out by particle bombardment at pressures ranging from thousands of atmospheres down to near vacuum. The understanding of interactions between activated gases and of plasma stability at low ion concentrations is of extreme importance in a number of fields.

Recently, interest has grown in the possibility of using heavy-ion bombardment for producing moderate electron densities in gases to investigate reactions between plasmas and solid surfaces. This is of great importance in the missile field, since these missiles travel with sufficient velocity in the rarified upper atmosphere to produce a surrounding sheath of ions that can react with the missile skin to produce surface damage.

The study of reaction kinetics in gases by means of radiation is contributing to our understanding of industrial chemical processes based on gas-phase reactions. It also appears that knowledge of gaseous reactions may contribute to our presently incomplete understanding of liquid-state phenomena.

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The beam intensities produced permit the use of these machines in studies requiring a high yield of reaction products. Because the energy and type of particle can be varied, it is possible to investigate linear energy transfer in a gas. The energy definition, considerably better than that obtainable with any other type of accelerator in the same energy range, and the applicability of pulsing techniques, make the Van de Graaff a precision instrument for the study of chemical reaction kinetics and the lifetime of the reactive components.

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22 August 1958, Volume 128, Number 3321 SCIENCE

CURRENT PROBLEMS IN RESEARCH

Formation of Elements in the Stars

To build all the elements requires that eight nuclear processes occur as the conditions become ripe.

Margaret and Geoffrey Burbidge

The origin of the chemical elements, from the lightest, hydrogen, to the heaviest, has always been a fascinating problem for physicists, chemists, and astronomers. Recently there have been developments in nuclear physics and in both theoretical and observational astrophysics which have made possible a new attack on this problem.

The raw material which must form the starting-point for any theory of the origin of the elements is a knowledge of the relative abundances, not only of the different chemical elements, but also of all the different isotopes of each element. The first question to be asked is: What is the relative abundance distribution among all the isotopes of every element in the material forming the crust of the earth? This can be answered by the geochemists, and more and more accurate results have become available in the last few years. The composition of meteorites can also be directly and accurately determined.

The next step, however, is harder. To determine the composition of the sun, spectroscopic analysis must be used, and this means that, with few exceptions, isotopic abundances cannot be determined. Also, information can be obtained only about those atoms which are excited to show spectral lines under the conditions of temperature and pressure found in the sun's atmosphere, and in the wavelength range transmitted by the earth's atmosphere.

With these reservations, however, it has been found that the differences in composition between the sun, the earth, and meteorites can be explained through the loss of the lighter and more volatile elements by the less heavy bodies in the early history of the solar system.

The next step, however, to ask whether the composition of all the stars in our galaxy, and of all other galaxies, is the same as that of the solar system, is a far more difficult problem. In the first place, so much less light is available from stars than from the sun that less powerful spectrographs have to be used, and less precise results are obtained. Despite the difficulties, however, and despite the large amount of labor involved in finding the composition of one single star, some results have been obtained for stars relatively near the sun, although for a pitifully small sample of stars compared with the 10^{11} or so stars that compose our galaxy. With some notable exceptions, which we shall discuss later, the composition of these stars, as far as it can be determined, is quite similar to that of the sun.

The gas which lies between the stars in our galaxy can also be studied, particularly where it lies close enough to hot stars so that its atoms are excited by their radiation and emit radiation of their own. As far as we can tell at present, this gas also has a composition fairly similar to that of the hot stars embedded in it.

To talk of an average composition of the material fairly near to the sun does, therefore, have meaning, so long as it is never forgotten that this average refers only to a small sample of our galaxy alone. However, another point to be remembered is that the spectroscopic analyses of the sun and stars refer only to their surface layers and do not necessarily give information about the composition of their interiors. Throughout most of the lifetimes of stars, mixing between their deep interiors and surfaces does not take place, and, as we shall see, nuclear transmutations of material must be happening in the interiors.

A schematic curve showing the relative abundances of the elements, plotted logarithmically against the atomic weight, A, is shown in Fig. 1. This curve is based on a recent weighting of all available results, geochemical and astrophysical, made by Suess and Urey (*1*). The first fact that stands out is that hydrogen, the lightest, is the most abundant element, and there is a steep decline in abundance with increasing atomic weight until one reaches about $A = 100$ (the elements molybdenum and ruthenium). After this point, the curve tends to flatten out.

Superimposed on this general trend are a number of peaks and separate groupings of elements which give the curve a very complicated appearance. The main features are the low-lying light elements lithium, beryllium, and boron; a group of elements between $A = 12$ and $A = 40$ lying above the general trend; a sharp peak centered on iron at $A = 56$; three sets of twin peaks near $A = 90$, 140, and 200; and finally, a group of isotopes between $A = 70$ and 200 lying below the main curve by a factor of about 100.

Starting from this observed abundance distribution, the possibility can be investigated that matter was created in as simple a form as possible (for example, in the form of pure hydrogen, the lightest and simplest chemical element, or in the form of the fundamental particles, protons, neutrons, and electrons and possibly their antiparticles, antipro-

The authors are on the staff of the Yerkes Observatory of the University of Chicago, William Bay, Wis.

tons, antineutrons, and positrons), and that the rest of the elements have been produced subsequently, at some time or times during the history of the universe, by physical processes, according to known physical laws. That this is the case is supported, as we shall see, by a linking between some of the complexities of the abundance curve and the properties of nuclei.

There are two major theories for the origin of the elements. In the first, it is supposed that the universe was created at a particular instant of time and has been expanding ever since. In the first few minutes of its existence all of the elements were built by reactions taking place in a mixture of fundamental particles—protons, neutrons, electrons, positrons, mesons, and radiation. The same physical laws which operate today are postulated to have been valid at that time and to have governed the ways in which these reactions occurred.

This theory was pursued during a period about ten years ago, mainly by Gamow and his chief collaborators, Alpher and Herman, although many other distinguished scientists—Fermi and Turkevitch, for example—also made important studies bearing on the subject. An extensive review article developing this point of view is available (*2*). Gamow called his theory the "ylem" theory, ylem (*3*) being his name for the hot primeval mixture of particles and radiation.

The alternative theory seeks to explain the building of the elements by suggesting that it has occurred, and is continuously occurring, in places where we know that the temperature and density are high enough for nuclear reactions and the transmutation of one element to another to occur. Such places are the interiors of stars; the structure of stars demands high temperatures and pressures here, and many people feel that it is preferable to build a theory upon known present-day conditions than upon a hypothetical state of the universe at some time in the past.

Also, the many complexities of the abundance curve can, as we shall show, be explained by the different sets of conditions that can occur at different stages of a star's evolutionary path, or in stars of different masses. These same complexities always proved a stumbling block to the ylem theory, since conditions that may be right for building some elements will not serve for others, and so short a time was available for the whole production of all the elements to take place that the conditions of temperature and pressure had to be rather rigidly specified.

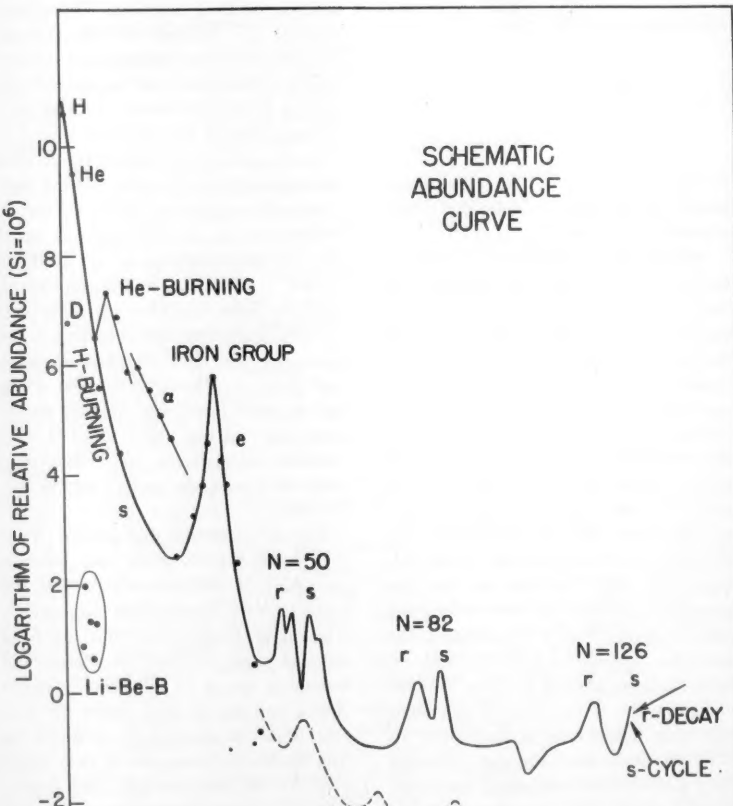

Fig. 1. Schematic curve of atomic abundances as a function of atomic weight based on the data of Suess and Urey (*1*). There is still considerable spread of the individual abundances about the curve illustrated, but the general features shown are now fairly well established. Note the overabundances relative to their neighbors of the α-particle nuclei $A = 16, 20, \ldots 40$, the peak at the iron-group nuclei, and the twin peaks at $A = 80$ and 90, at 130 and 138, and at 194 and 208. [Courtesy *Reviews of Modern Physics* (*19*)]

Cosmological Background

The ylem theory, based upon a giant explosion that occurs at the creation of the universe and starts its expansion, is obviously tied to a particular class of cosmological models. It also predicts that the relative abundances of the elements, except for the possible effects of later modifying processes, will be uniform throughout the universe.

A new approach to the cosmological problem, the steady-state theory of Hoyle, Bondi, and Gold (*4*) has been proposed. In this theory, the rate of disappearance of matter at the boundary of the expanding universe is balanced by the continuous creation of matter at a uniform rate throughout space; the universe had no beginning and will continue for an infinite time. This theory of course would be quite incompatible with Gamow's ylem origin of the elements.

There has also been a recent revival of interest in oscillating world models, which are also incompatible with an ylem theory. Furthermore, the possible existence of antimatter on the universal scale (*5*) may also lead to profound changes in cosmological theories.

Since it has sometimes been proposed that each of the two theories of the origin of the elements is supported by a particular cosmological model, or vice

versa, it is of importance to say something about the observational evidence concerning the cosmological problem at the present time.

A number of cosmological tests, all exceedingly difficult, are available, but none has yet led to any noticeable weeding out of the available theories. Some years ago Stebbins and Whitford (*6*) thought that they had found an apparent reddening of distant galaxies, over and above that expected from their velocities of recession which cause their spectra to be shifted to the red. Such an effect would imply that distant parts of space are populated by galaxies with different properties from those in our own neighborhood, and this is contrary to the predictions of the steady-state theory. Recently, however, Whitford and Code have found that this effect, which is extremely hard to measure, probably does not exist (*7*).

Attempts to distinguish between different cosmological models by analyzing the distributions of very distant radio sources have led to complete confusion so far and to very considerable disagreement between radio astronomers in England and Australia who use different techniques (*8*).

The optical method of using the relation between velocity and distance, as deduced from measured redshifts and brightnesses for distant clusters of galaxies, has led to great advances in the hands of Hubble, Humason, Mayall, and Sandage. However, the spectroscopic techniques have now been pushed practically to the limit possible with the 200-inch telescope (photoelectric photometry may lead to further advances in this field, since it is possible to measure the colors of extremely faint galaxies, but so far the results are disappointingly few). In 1956 all of the results then available were described (*9*). The velocity-distance relation was shown to be linear out to values of about 60,000 kilometers per second. However, the curvature in this relation beyond this point which would, if determined precisely, enable us to exclude some cosmological models, remained very uncertain. The value of the Hubble constant was found to be 180 kilometers per second per 10^6 parsec, corresponding to an "age" of 5.4×10^9 years, an increase of a factor of about three from that given by Hubble and Humason some twenty years before. This included all of the corrections previously suggested, particularly that enunciated by Baade (a result which had been partly foreshadowed by Mineur). Since 1956 a further revision in the distance scale has been proposed by Sandage (*10*). The Hubble constant derived by Sandage is only about 75 kilometers per second per 10^6 parsec, corresponding to an "age" of about 13×10^9 years (*11*). We are warned by Sandage that many uncertainties still remain.

Another cosmological test is available in the analysis of the distribution of external galaxies and clusters of galaxies, but although much work has been done in this field, particularly by Shane and his collaborators and by Zwicky and Abell, no definitive results are available.

Clearly, therefore, at the present time no cosmological arguments can be adduced in favor of one or another of the theories of the origin of the elements. However, it is fair to say at the present time that the idea that all of the elements have been built in the stars may be compatible with whatever cosmological model best represents the universe. For example, in the steady-state theory it is supposed that matter is created at a given rate which is determined by the value of the Hubble constant. However, so far, apart from a preliminary attempt by Pirani in the framework of the classical theory, no theory has been advanced to describe the way in which particles are created, but it has generally been supposed that the process involves either stable fundamental particles, protons and electrons, or else unstable particles such as neutrons and heavy mesons. No suggestion has ever been made that heavy nuclei are continuously created, so that from this aspect the building of elements in stars is an important adjunct to the steady-state theory. On the other hand, such a theory is also compatible with evolutionary or exploding cosmological models. In fact it might be proposed that some synthesizing processes, perhaps the production of deuterium and some helium in the ylem, followed by the production of all of the other isotopes in the interiors of stars after galaxies were formed, would overcome the difficulty in the stellar synthesis theory of producing enough deuterium, a problem which we shall discuss later.

Growth of Ideas Concerning Stellar Synthesis

As might be expected, the basic steps in the development of the stellar synthesis theory have been made on the heels of the growth in our knowledge of nuclear physics. The earliest attempts were those by Atkinson and Houtermans nearly thirty years ago to explain the sources of stellar energy in terms of the transmutation of light elements into heavy ones. These led Atkinson (*12*) to attempt to show that all of the elements could be built in the stars. The attempt was a complete failure, simply because understanding of the structure of nuclei was rudimentary at that time.

The first and most important step forward was the demonstration in 1938 by Bethe (*13*) and von Weizsäcker (*14*) that the major source of a star's energy throughout its life is the conversion of hydrogen to helium. This also showed that as a star grows older its chemical composition changes. In the decade following the work of Bethe and von Weizsäcker a number of attempts were made to consider the synthesis of the elements by use of the information on binding energies and other data which were gradually accumulating. In their attempt, Henrich and Chandrasekhar used the concept of statistical equilibrium, trying to show that all of the elements could be built at a unique temperature and density. Later extensive work in this direction was carried out in Sweden by Klein and his collaborators. The conditions for synthesis were always found to be far more extreme than any which might be expected in stars at the present time: also it was easy to see that a single process could not be held accountable for the production of all of the elements. Van Albaba considered the problem from a somewhat different direction, but in 1946 an important step forward was made by Hoyle (*15*), who showed that at least the peak in the abundance curve centered on Fe^{56} could be produced under extreme conditions of temperature and density in the interiors of stars. Hoyle believed that these conditions applied just before a star reached the end of its life and exploded as a supernova, and he proposed a possible mechanism which could trigger such an explosion. Although it was clear by then that several processes must be involved if all the elements were to be built in stars, and most of these processes still remained unknown, Hoyle was very strongly of the opinion that all these processes did occur.

The next important step forward was made by Salpeter and by Hoyle (*16*), who pointed out that although the nucleus Be^8 is unstable and spontaneously disintegrates into two α-particles, under suitable conditions in the interiors of stars the reactions

$$He^4 + He^4 \rightleftharpoons Be^8$$
$$Be^8 + He^4 \rightleftharpoons C^{12*} \rightarrow C^{12} + \gamma$$

could take place successively. This overcame the difficulty of synthesizing isotopes heavier than He^4, a difficulty which was particularly acute for the ylem theory since there are no stable nuclei of masses 5 and 8. Experimental confirmation of this has been made at the Kellogg Radiation Laboratory, California Institute of Technology (*17*). Recently this has encouraged some of the proponents of the ylem theory in Japan to propose that the initial conditions in the ylem are suitable for this process to occur.

Since then, there have been a number of major developments, particularly the discovery that at certain stages in a star's life reactions which lead to neutron production may take place, and some astrophysical evidence to show that transuranic elements can be built in supernova explosions. These have all led us to believe that a strong case can be made out for supposing that all of the elements were built in the stars. However, before proceeding to give a detailed account of this work it is necessary to make a digression in order to explain some of the aspects of the evolution of stars which are involved.

Evolution of Stars

When a star first condenses out of the interstellar gas and dust, it goes through a period of gravitational contraction and eventually, when its central temperature becomes sufficiently high, it begins to obtain its energy from the conversion of hydrogen to helium. Now the luminosity of such a star depends upon its mass according to a law of the form

$$L \propto M^{a}$$

where $\alpha \approx 3$ to 4 for stars more massive than the sun, and $\alpha \approx 2$ for stars of very low mass. The surface temperature is also determined by the mass. If the two quantities which can fairly easily be measured for the nearer stars, the surface temperature and the energy radiated, are plotted, most of the stars lie in a fairly narrow band shown in Fig. 2, called the "main sequence." In addition there are some stars at the upper right of the diagram. Since these stars have high luminosities yet low surface temperatures, they must have large radii; they are called the red giants. Such stars must have different structures from the main-sequence stars.

Let us consider what happens to a star which has just condensed out of the

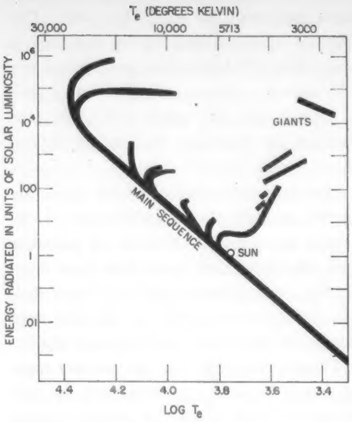

Fig. 2. Schematic plot of luminosity (in solar units) versus logarithm of T_e (approximate surface temperature) for stars in a number of star clusters. The black bands are the regions where the stars occur (relative density of points is not indicated). The point for the sun is also plotted. Most of the stars lie on or just to the right of the main sequence that is common to all the clusters. Many of the clusters also contain a few giant stars of low surface temperature, toward the top right-hand part of the diagram. In each cluster the distribution of stars breaks away to the right from the main sequence and comes to an abrupt end, with a well-marked gap between these stars and the giants. The position of the end of the main sequence provides a means of determining the age of clusters. Those in the figure range from 10^6 years (brightest stars) to 5×10^9 years (break-off point just above the sun). [Adapted from the work of Sandage (*18*)]

interstellar gas and arrived on the main sequence. It will begin to convert hydrogen to helium in its central core. A number of workers, Mestel, Öpik, and Sweet, have shown that, except for the stars of very small mass, there is no mixing between the core and the envelope of such a star. After a time, the star will have developed an inhomogeneity in composition between its core and envelope, and its structure will change slightly so that it remains in equilibrium under these changed conditions. This means that it will become slightly brighter and move a little above the main sequence in the luminosity-temperature (L-T) diagram (Fig. 2).

It was first shown by Schoenberg and Chandrasekhar that by the time the helium core has grown to contain about 10 percent of the total mass, the star can no longer remain in equilibrium unless it changes its structure drastically. What happens as this point is reached is that its core contracts, releasing gravitational energy to supplement its energy output and heat up its interior, while the outer envelope expands greatly and cools. The star thus moves rapidly to the right in the luminosity-temperature diagram and becomes a red giant. Such a star will now have an inert (as far as energy from hydrogen-burning is concerned) helium core, a shell around this which still contains hydrogen and which is the main source of its energy, and an extended envelope composed of the original material of the star. As the helium core goes on growing, it continues to contract and heat, until eventually it becomes hot and dense enough for nuclei with charges greater than hydrogen to interact. Thus the Salpeter reactions leading to the production of C^{12} can take place.

The fact that stars rapidly leave the main sequence region when the hydrogen in about 10 percent of the mass is consumed provides a means of dating groups of stars. A cluster of stars can be assumed to consist of stars with a range of masses, all of the same age. The more massive stars will reach the 10-percent limit more rapidly than the less massive ones because of the power-law form of the relation between mass and luminosity. A cluster of stars of any given age will have a main sequence extending up to a well-defined point; all stars originally on the main sequence above this point will have become red giants and then have evolved even further. This is exactly what is observed: Fig. 2 [adapted from the work of Sandage (*18*)] is a composite luminosity-temperature diagram for a number of star clusters of different ages. Each cluster has a well-defined termination to its main sequence from which its age can be deduced.

As a star evolves further we can imagine the process to repeat itself: helium as a nuclear fuel will begin to be exhausted, so that the core must contract further, providing more gravitational energy, and the central regions will become still hotter. This means that, successively, nuclei with greater and greater Z values can overcome the Coulomb barrier and interact, thus building heavier and heavier nuclei and releasing energy, though the energy release at the later stages is small compared with that released by hydrogen-burning. This process can continue until the most tightly bound nuclei centered around Fe^{56}, those at the bottom of the packing-fraction curve, are reached.

Stellar models have been computed for main-sequence and red-giant stars, so

that we have detailed information on the astrophysical conditions for hydrogen-burning and helium-burning, but none is available as yet for the later stages of evolution. Most of this work has been done in recent years by Schwarzschild and Hoyle and their collaborators. But this qualitative argument for the later sequence of events is logical; a star, as long as it contains nuclear fuel, has a built-in mechanism for adjusting its structure, when one fuel is exhausted, so as to heat up its interior until the next heavier fuel is brought into operation.

Finally, there will come a time when a star must have exhausted all of its fuel. This is a long time for stars of the same mass as the sun ($\sim 10^{11}$ years), but it is only of the order of tens of millions of years for the most massive stars. Consequently, stars must continually be dying and fresh ones must be forming out of the interstellar gas. When a star nears the end of its life, it may either undergo a gigantic catastrophic explosion as a supernova or settle down quietly in the form of collapsed or degenerate matter as a white dwarf, or both. However, Chandrasekhar proved that a white dwarf is stable only if it has less than a certain limiting mass, which is about 1.4 solar masses, though this is slightly dependent on the chemical composition. Therefore all the more massive stars must lose some of their mass, either steadily or explosively, before they can settle down as white dwarfs.

We shall consider the consequences of this continual birth and death of stars later, but now let us turn to the various nuclear processes which can occur as conditions in stellar interiors become right for them. In all, eight processes (see Fig. 3) are required to build all of the elements, and the work described in the remainder of this article has been taken from an extensive paper on all aspects of the problem (*19*).

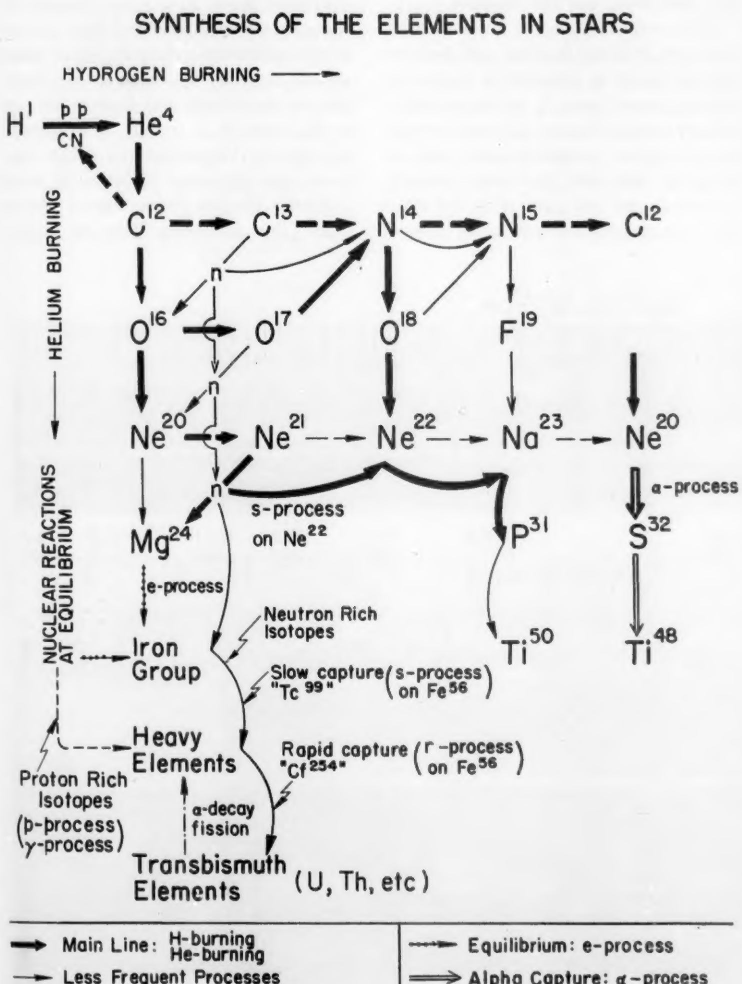

Fig. 3. A schematic diagram of the nuclear processes by which the synthesis of the elements in stars takes place. Elements synthesized by interactions with protons (hydrogen-burning) are listed horizontally. Elements synthesized by interactions with alpha particles (helium-burning) and by still more complicated processes are listed vertically. The details of the production of all of the known stable isotopes of carbon, nitrogen, oxygen, fluorine, neon, and sodium are shown completely. Neutron capture processes by which the highly charged heavy elements are synthesized are indicated by curved arrows. [Courtesy *Reviews of Modern Physics* (*19*)]

Hydrogen-Burning and Helium-Burning

The first process is the basic one of the conversion of hydrogen to helium, either through the carbon-nitrogen cycle for stars on the brighter part of the main sequence (masses $\geqq 2$ solar masses), or by the proton-proton chain for stars in the lower part of the main sequence. The reactions involved in the carbon-nitrogen cycle are:

$$C^{12}(p,\gamma)N^{13}(\beta^+\nu_+)C^{13}$$
$$C^{13}(p,\gamma)N^{14}$$
$$N^{14}(p,\gamma)O^{15}(\beta^+\nu_+)N^{15}$$
$$N^{15}(p,\alpha)C^{12}.$$

Laboratory studies of these reactions have been under way at the Kellogg Radiation Laboratory for many years, and recently at the University of California Radiation Laboratory at Livermore. Full references are given elsewhere (*19*). Reactions in the proton-proton chain are given in Fig. 4. Hydrogen-burning also takes place in the shell around the core after the star has left the main sequence and become a red giant. It occurs over a range of stellar temperatures from a few million degrees upward.

The basic reactions in helium-burning which were mentioned above reduce to

$$3He^4 \rightarrow C^{12*} \rightarrow C^{12} + \gamma.$$

For this process to occur, temperatures in excess of 10^8 degrees and densities upward of 10^3 grams per cubic centimeter are required. These conditions are known

$$H^1(p,\beta^+\nu_+)H^2(p,\gamma)He^3 \begin{cases} (He^3,2p)He^4 \\ (\alpha,\gamma)Be^7 \begin{cases} (e^-,\nu_+)Li^7(p,\gamma)2He^4 \\ (p,\gamma)B^8(\beta^+\nu_+)Be^{8*}(\alpha)He^4 \end{cases} \end{cases}$$

Fig. 4. Reactions in the proton-proton chain.

to prevail in the cores of red-giant stars, and they are almost certainly achieved also in the evolutionary stages subsequent to the red giants. Under similar conditions the further reactions

$$C^{12}(\alpha,\gamma)O^{16}(\alpha,\gamma)Ne^{20}$$

and, to a small degree,

$$Ne^{20}(\alpha,\gamma)Mg^{24}$$

can also take place. The successive captures of α-particles effectively cease at this point because of the increasing strength of the Coulomb barrier.

Helium-burning yields only about one-tenth as much energy, per gram of material, as was provided by hydrogen-burning. Although it is an important source of energy, therefore, it cannot last as long as hydrogen-burning before all the helium fuel in a star will be consumed. The time scale is probably 10^7 to 10^8 years. Provided that nuclei which are made by helium-burning—that is, C^{12}, O^{16}, Ne^{20}—are present already, hydrogen-burning in a gas containing these isotopes will synthesize the majority of the less abundant isotopes of carbon, oxygen, and neon, and also nitrogen.

Observational evidence for the occurrence of hydrogen-burning and helium-burning might be expected to appear on the surfaces of stars in advanced evolutionary stages, because, although mixing does not occur in main-sequence stars, it probably does take place later, possibly already in the red-giant stage for massive stars. Several different kinds of stars are observed whose spectra show the products of hydrogen- and helium-burning in abnormally large abundance, and also deficiency of hydrogen. Some are illustrated in Figs. 5 and 6.

The star υ Sagittarii (Fig. 5) has very weak hydrogen lines in its spectrum, compared with the normal star of similar surface temperature, η Leonis. There are even more extreme examples, showing no hydrogen at all. Such stars tend to have strong helium lines and may be lacking in oxygen, which is destroyed in hydrogen-burning at high enough temperatures. Some have large amounts of nitrogen, which is produced from carbon in the carbon-nitrogen cycle. Many white dwarfs show no hydrogen at all; those that do show some may have picked up a thin skin of it during their passage through the interstellar gas, which contains about 75 percent hydrogen by mass.

Among the red giants, there are some stars (Fig. 6) which have an abnor-

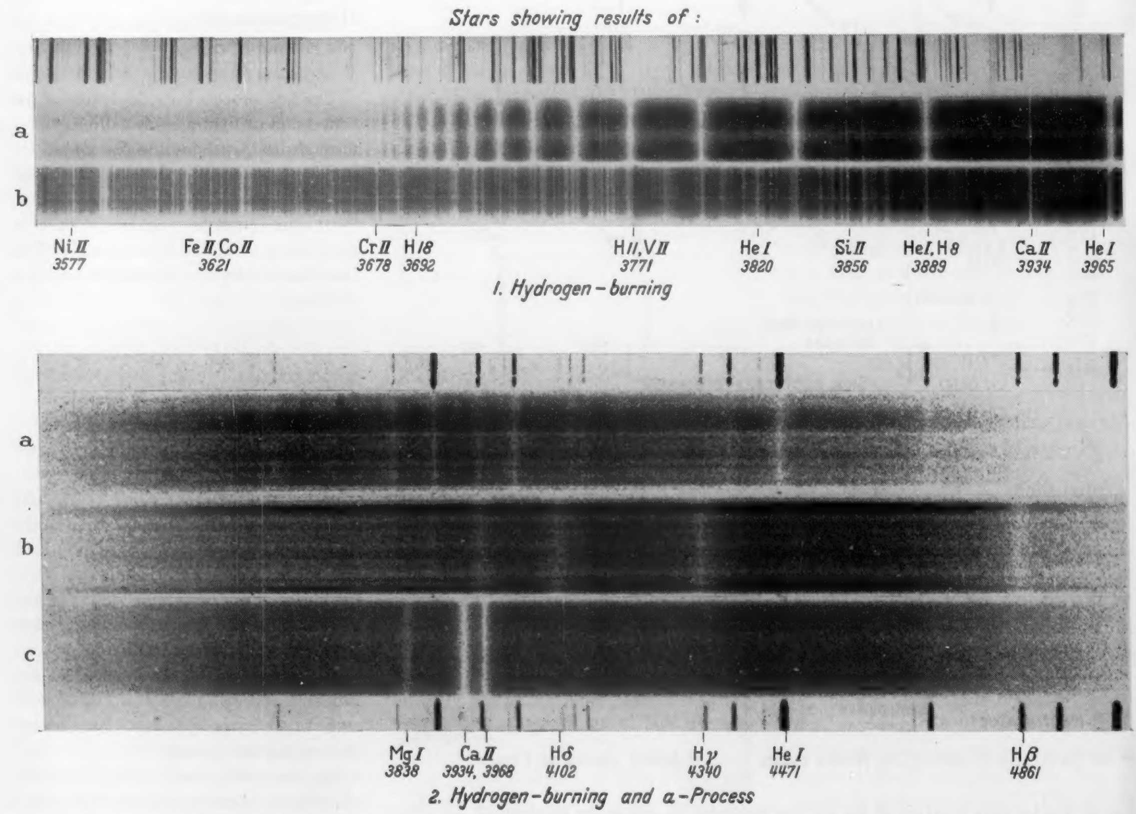

Fig. 5. Portions of the spectra of stars showing the results of hydrogen-burning and possibly the α-process. Top: (*a*) Normal star, η Leonis, showing strong Balmer lines of hydrogen and strong absorption at the series limit. (*b*) Peculiar star, υ Sagittarii, in which hydrogen has a much smaller abundance than normal. Bottom: (*a*) White dwarf, L 1573-31, in which hydrogen is apparently absent. The comparison spectrum above the star is of a helium discharge tube; note the lines of helium in the star's spectrum. (*b*) White dwarf, L 770-3, which shows broad lines due to hydrogen only, for comparison with (*a*) and (*c*). (*c*) White dwarf, Ross 640, which shows only the two lines due to calcium and a feature due to magnesium. All the spectrograms in this plate were obtained by J. L. Greenstein; the upper two are McDonald Observatory plates, and the lower three are Palomar Observatory plates.

mally high abundance of carbon relative to oxygen. Possibly the carbon has been produced by helium-burning. In these cool stars bands due to the molecule C_2 show, and thus isotopic abundances, C^{12}/C^{13}, can be determined. Most carbon stars have $C^{12}/C^{13} = 3$ or 4, in distinction from the material of the solar system, where $C^{12}/C^{13} = 90$. Now an equilibrium ratio of 4.6 is set up by the carbon-nitrogen cycle; these stars therefore probably have on their surfaces matter which has been through a hydrogen-burning region.

There are some even more peculiar carbon stars which apparently have very little hydrogen and no C^{13}. Perhaps C^{12}, produced in the interior, did not mix out to the surface until almost all of the hydrogen had been consumed throughout the star, and thus never passed through a hydrogen-burning region.

The Wolf-Rayet stars are massive, very hot, apparently unstable stars, which are highly evolved. In some, carbon is very abundant, in others, nitrogen. Such stars probably show the results of hydrogen- and helium-burning combined.

Although all these examples are striking, they are, except for the white dwarfs, not numerous compared with the total number of stars in our galaxy. This may be because stars at so late an evolutionary stage cannot last long, so that the chances of catching a star at this stage are correspondingly small.

The α-Process

When helium is exhausted in the core of a star, the core must shrink and release gravitational energy, some of which will heat the core. When the core reaches a temperature of about 10^9 degrees, the gamma rays will become energetic enough to remove the last α-particles bound by nuclei, in particular by Ne^{20}. These can be captured by remaining Ne^{20} to make Mg^{24}. The reactions are

$$Ne^{20} + \gamma \rightarrow O^{16} + He^{4} - 4.75 \text{ Mev}$$
$$Ne^{20} + He^{4} \rightarrow Mg^{24} + \gamma + 9.31 \text{ Mev}$$

Thus more energy is released by the capture than was used in freeing the α-particles, so that this process provides a nuclear fuel. Further reactions utilizing the α-particles freed from Ne^{20} can also take place; they are

$$Mg^{24}(\alpha,\gamma)Si^{28}(\alpha,\gamma)S^{32}$$

and so forth. By such reactions the four-structure nuclei, lying above their neighbors in the abundance curve (Fig. 1), will be built at least up to Ca^{40}, and probably some Ca^{44} and Ti^{48} also. We have called this the α-process (*19*). The time scale for this process is probably about 100 to 10,000 years; consequently it probably occurs toward the end of a star's active life.

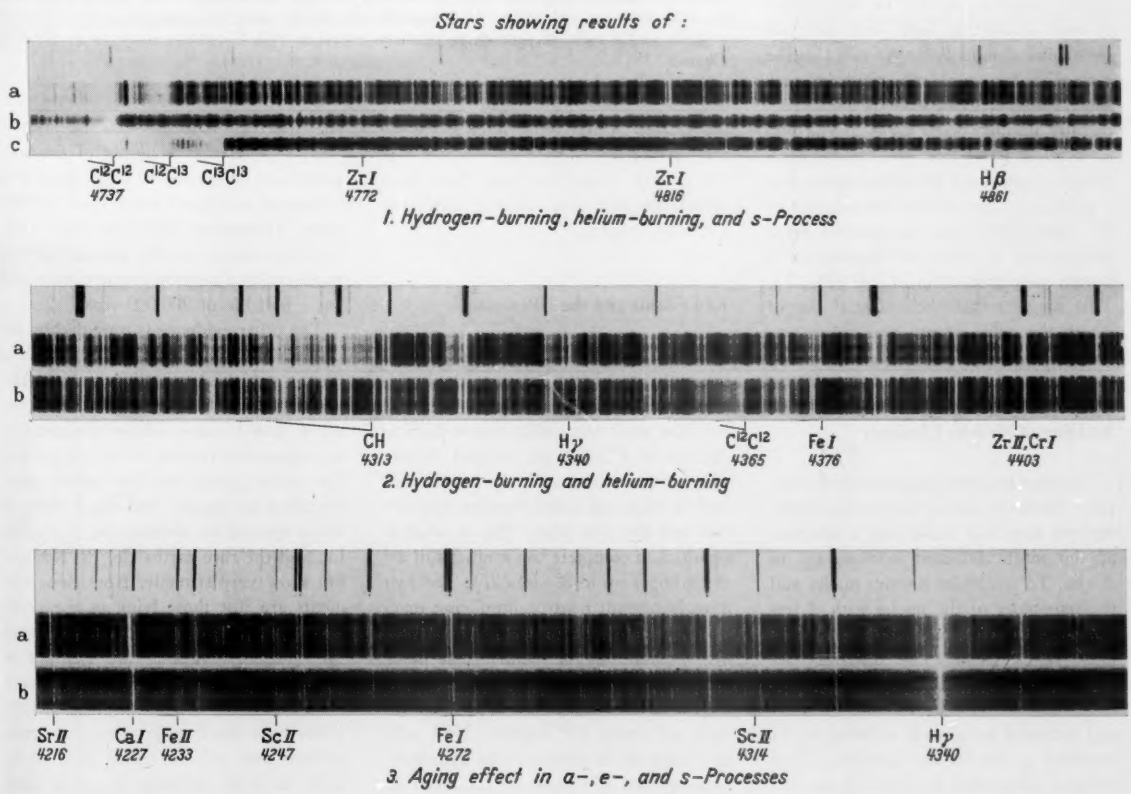

Fig. 6. Portions of the spectra of stars showing different aspects of element synthesis. Top: (*a*) Normal carbon star, *X* Cancri, which has $C^{12}/C^{13} \sim 3$ or 4. (*b*) Peculiar carbon star, HD 137613, which shows no C^{13} bands, and in which hydrogen is apparently weak. (*c*) Normal carbon star, HD 52432, which has $C^{12}/C^{13} \sim 3$ or 4. Note that zirconium lines appear to be strongest in (*a*). Middle: (*a*) Normal carbon star, HD 156074, showing the CH band and the hydrogen line Hγ. (*b*) Peculiar carbon star, HD 182040, in which CH is not seen, although the weak band of C_2 at λ 4365 is visible. Hγ is also very weak, indicating that hydrogen has a low abundance. Bottom: (*a*) Normal star, ξ Pegasi. (*b*) Peculiar star, HD 19445, which has a slightly lower temperature than ξ Pegasi, yet all lines but hydrogen are much weakened, showing that the abundances of α-, *e*-, and *s*-process elements are much lower than normal ("aging" effect). The middle two spectra were obtained by J. L. Greenstein, the remainder, with the exception of HD 137613, by E. M. and G. R. Burbidge.

In the spectrum of the white dwarf Ross 640, shown in Fig. 5, there are no features other than those attributable to magnesium and calcium (whose most abundant isotopes are produced by the α-process). Possibly this star is an example of one which has undergone this process.

The Iron Peak: the *e*-Process

After the α-process has ceased to provide energy, the star must contract further if it is to remain stable. When temperatures as high as 3×10^9 degrees are reached, a great profusion of reactions will occur, and conditions of statistical equilibrium will be reached. On this basis it is easy to calculate the relative abundances of the nuclei that will be built; the only parameters needed are the temperature and the ratio of the number of free protons to free neutrons (which is determined by the density). The most tightly bound nuclei will be built in the greatest quantities, and these are just the nuclei around Fe^{56}. We call this the *e*-process. Its time scale must be very short, of the order of seconds, and consequently it must occur right at the end of a star's active life, just before catastrophic explosion. Calculation shows that a good fit to the relative abundances of the solar system can be obtained for a temperature of 3.78×10^9 degrees and a proton-to-neutron ratio of 300 (Fig. 7). This suggests that the material out of which the solar system was made was once exposed to these conditions.

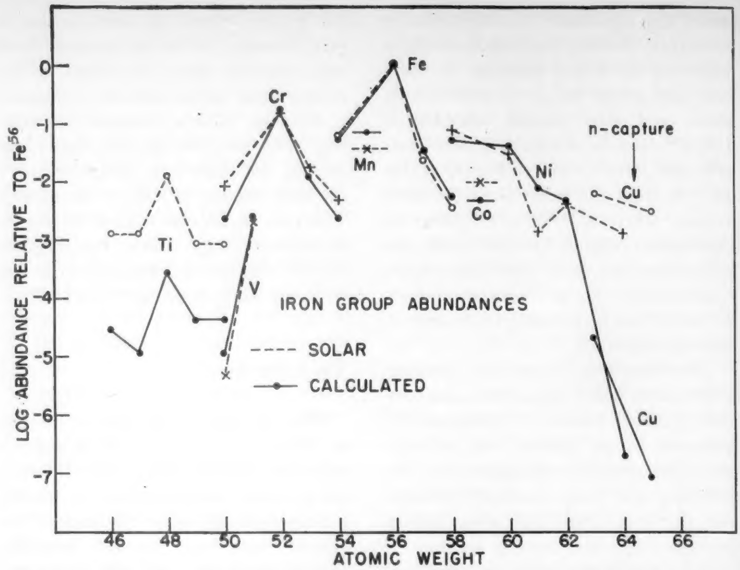

Fig. 7. Logarithmic abundance curve for the iron group isotopes relative to the abundance of Fe^{56}. The points connected by dashed lines are the solar abundances in which terrestrial isotope ratios are used to calculate isotope abundances. The points connected by solid lines are calculated from equilibrium theory using a temperature of 3.78×10^9 degrees and a ratio of protons to neutrons equal to 300. [Courtesy *Reviews of Modern Physics* (*19*)]

Building of Heavier Elements

The four processes just described complete the energy-giving nuclear reactions, and yet they will build only a selection of the most abundant isotopes up to $A = 60$. To synthesize heavier nuclei and the remainder of the nuclei with A less than 60, clearly some further processes must be at work. The discovery by Cameron (*20*) that under certain conditions neutrons can be released in stars and captured by already existing nuclei provided a clue to the problem. Very different effects will be achieved, according to whether the neutrons are supplied slowly or rapidly. In the first case, when unstable nuclei are reached in a neutron-capture chain (shown schematically in Fig. 8) they have time to decay by β-emission before capturing another neutron, but in the second case they do not, and building proceeds through β-unstable nuclei, which must later decay to their stable forms after the neutron flux has ceased. These two cases have been called the *s*-process (slow) and the *r*-process (rapid).

Red Giants and the *s*-Process

If the iron-peak elements are present in ample abundance in a star, the build-up chain will start with them and will continue until the radioactive α-particle emitters at $A > 209$ are reached. Otherwise, it may start at a lighter element such as neon and build elements between this and the iron peak. This is what is required to complete the synthesis of all the isotopes up to $A = 60$ (*21*). The two most important neutron-producing reactions are $C^{13}(\alpha,n)O^{16}$ and $Ne^{21}(\alpha,n)Mg^{24}$; conditions for them to take place can occur in the interiors of red-giant stars with large helium cores at temperatures of about 10^8 degrees. Ne^{21} will have been made previously by hydrogen-burning, and C^{13} may be produced in sufficient quantity if some mixing takes place between the core, containing C^{12} built by helium-burning, and the hydrogen in the envelope.

There is good observational evidence that this process occurs in red giant stars. In the first place, the identification of the unstable element technetium in the spectra of some stars by Merrill (*22*) showed that a supply of neutrons must have been released and captured in a time of not much more than 100,000 years. Technetium does not occur naturally on earth, but the isotope Tc^{99} is produced in a neutron-capture chain and has a half-life of 200,000 years.

The other evidence is provided by the division of the red giant stars into three groups which have different spectral characteristics. The most common are the K and M stars, whose compositions are apparently similar to that of the sun. The other groups are the carbon stars, described previously, and the S stars, in whose spectra the elements Sr, Y, Zr, Ba, La, and the rare earths Ce, Pr, Nd, and Sm show very strongly. Now these elements are just those lying in the peaks in the abundance curve at $A = 90$ and 140 (Fig. 1). Among the isotopes in these regions are those which have closed shells of 50 and 82 neutrons, respectively. These have small neutron-capture cross-sections and will therefore tend to be built in high abundance, outstanding above their neighbors. Figure 9 shows the spectra of two stars in which the *s*-process has been operating. The star HD 46407 is a giant of slightly higher temperature than the S stars, but shows the same effects, and was analyzed quantitatively by us (*23*).

Further evidence for the *s*-process

comes from the solar-system abundances of those isotopes believed to have been built this way in the two regions $23 \leq A \leq 46$ and $63 \leq A \leq 209$. In both, the products of the neutron-capture cross-sections and the abundances, plotted against A, lie on a smooth curve as would be expected in a neutron-capture chain. Measures of cross-sections for many of these heavy isotopes have been made recently at Oak Ridge and Livermore, and when these alone are used, the curve is very well-defined and smooth. Furthermore, plots for the isotopes not made by the *s*-process are scattered at random on the graph!

Supernovae and the *r*-Process

The *r*-process will occur at any point at which a very large flux of neutrons can be generated in condensed matter in a few seconds. For example, much of the radioactive debris produced in terrestrial nuclear explosions is synthesized by a man-made *r*-process. In a similar way the astrophysical circumstances of the *r*-process must be the rapid generation of energy, that is, violent explosion. The most immense stellar explosions known are supernova outbursts in which it is believed that in a very short period (seconds, minutes, or hours) a considerable fraction of the mass of a star is ejected at very high velocities ($\sim$ 10,000 kilometers per second), while the light output of the star increases tremendously, probably by a factor $\sim 10^{10}$ in some cases. The light then slowly declines over a period of years.

The light-curves of some supernovae, published by Baade, are shown in Fig. 10. An important clue to the mechanism of supernova outbursts has been given by the shapes of some of these curves. Between 50 and 100 days after maximum the curves achieve an exponential decline with a half-life of about 55 days, which continues for several hundred days in the case of the supernova followed the longest by Baade, that in the external galaxy IC 4182. It is generally believed that this exponential decline can be explained only by supposing that it is due to energy released by a radioactive nucleus with this half-life. The first suggestion was made by Borst, who proposed that Be^7 with a half-life of 53 days was responsible.

More recently it has been proposed that the transuranic isotope Cf^{254}, which was made in the Bikini nuclear tests in 1952 (and in successive tests), and which has a half-life of 56.2 ± 0.7 days, is responsible (*24*). This isotope decays by spontaneous fission and releases a large amount of energy, about 200 Mev per nucleus. Moreover, it is an isotope which will be built in the *r*-process capture chain. Thus, if we accept this suggestion, the form of the supernova light curves provides the only evidence of where the *r*-process occurs. When the Cf^{254} is built the other *r*-process nuclei will also be made, the chain of neutron capture extending up to about $A = 260$, at which point the rate at which nuclei spontaneously decay becomes faster than the rate of neutron capture, so that the chain is effectively broken.

It has been argued (*19*) that the thermonuclear explosion giving rise to the

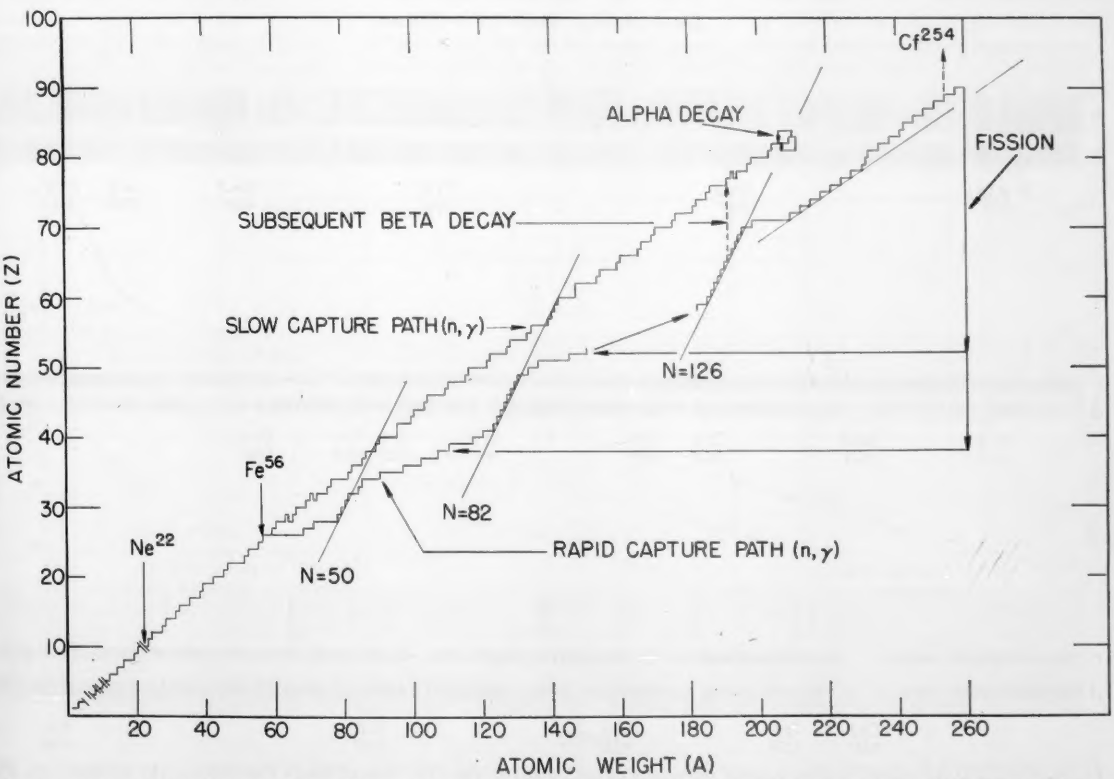

Fig. 8. Schematic plot showing how heavier nuclei are built from lighter ones by neutron capture on either a slow (*s*-process) or a rapid (*r*-process) time scale. The atomic number Z (charge of the nucleus) is plotted against the atomic weight A. The build-up goes from the bottom left-hand corner upward and to the right. Capture of a neutron moves a nucleus one unit to the right, and β-decay moves it one unit upward. At the closed shells of neutrons ($N = A - Z = 50$, 82, and 126) addition of a further neutron is more difficult, and excess abundances build up at these points. [Courtesy *Reviews of Modern Physics* (*19*)]

r-process is triggered in the following way. If the core of a star continues to shrink until a temperature of between 7 and 8×10^9 degrees is reached, the equations of statistical equilibrium show that the material will be broken up from Fe^{56} to He^4. The energy required for this to happen can come only from the gravitational energy which will practically all be used, so that mechanical equilibrium cannot be maintained and the core will implode. Now the material in the outer regions of the star normally possesses a thermal energy which is far less than its gravitational potential energy. If, therefore, any abnormal process leads to the thermal energy suddenly increasing to a value comparable with the gravitational energy, this means that the material is suddenly heated. This is what will happen when the core implodes. It has been estimated that as the outer regions fall inward temperatures of 10^8 degrees will be reached. This sudden heating will be sufficient to generate much energy by (p,γ) reactions and a large flux of neutrons through the (α,n) reactions described earlier. What fraction of these neutrons will be available to generate the r-process chain is not certain, but an additional supply of neutrons will have been provided a few seconds earlier in the conversion of Fe^{56} to He^4. The energy release triggered by this sudden heating leads to the ejection of matter and to the sudden increase in brightness of the star.

Calculation shows that the observed abundances of the r-process isotopes can be well reproduced when such a model is assumed. A further point of interest is that it is possible to calculate the initial ratio of the abundances of U^{235} and U^{238} which are built. Then, by using the abundance ratio of these isotopes found in the earth and the meteorites today and their decay rates, it is possible to determine the time which has elapsed since the isotopes were made in a supernova explosion, or in a number of such explosions. The minimum age is about 6.6×10^9 years. It does not follow, of course, that the solar system was formed at that time.

Remainder of the Heavy Elements: the p-Process

The neutron capture processes account satisfactorily for the great majority of the heavy elements, but there remain a few isotopes which are in all cases *proton-rich* nuclei, and which cannot be produced by either the s- or the r-processes. All these isotopes are less abundant than the adjacent nuclei in the solar system material by factors of 100 or more (see Fig. 1). Such nuclei could be produced by the modifying processes of proton capture (p,γ) or the ejection of neutrons by γ-rays, (γ,n), acting upon nuclei already made by the s- or r-processes. The relative abundances of these isotopes show that (p,γ) reactions are more probably responsible; hence we have called this the p-process. It might take place in those supernova explosions involving stars that still have considerable hydrogen left in their envelopes. There is some evidence suggesting that the more massive stars explode while there is still some hydrogen left. Alter-

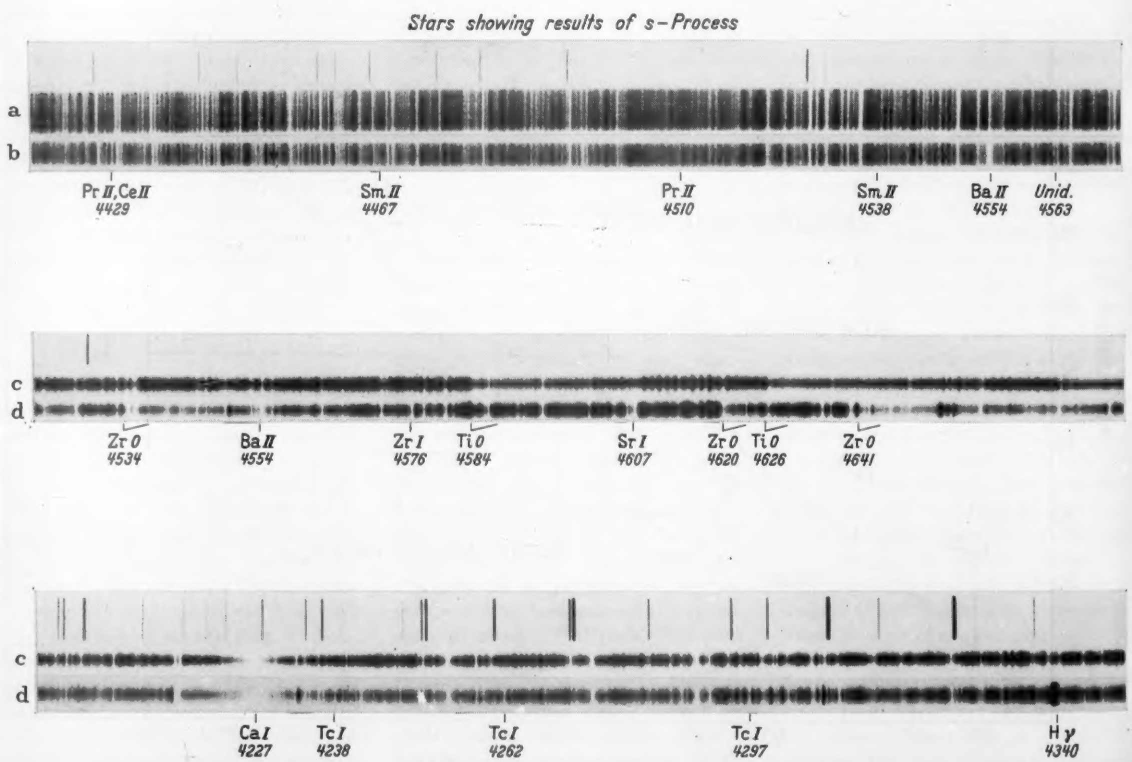

Fig. 9. Portions of the spectra of stars showing the results of the s-process. Top: (a) Normal star, κ Geminorum. (b) Peculiar star, HD 46407, showing the strengthening of the lines due to the s-process elements barium and some rare earths. Middle: (c) M-type star, 56 Leonis, showing TiO bands at λ 4584 and λ 4626. (d) S-type star, R Andromedae, showing ZrO bands which replace the TiO bands. Lines due to strontium, zirconium, and barium are all strengthened. Bottom: (c) Another spectral region of the M-type star, 56 Leonis; note that technetium lines are weak or absent. (d) R Andromedae; note the strong lines of technetium. The spectrum of R Andromedae was obtained by P. W. Merrill, the upper two spectra by E. M. and G. R. Burbidge.

natively, the p-process might occur in the outer parts of the supernovae thought to be responsible for the r-process.

Light Elements

In a comprehensive theory the production of the light elements deuterium, lithium, beryllium, and boron must be accounted for. The latter three are rare in the solar system, as is shown by Fig. 1, but deuterium comprises about one part in 6000 of the hydrogen in the oceans on earth. All these elements are readily destroyed by reactions with protons at fairly low temperatures, so that in the center of the sun, for example, deuterium can have an equilibrium abundance of only 10^{-17} that of hydrogen. In a stellar origin theory, therefore, these light elements constitute a problem.

One solution may lie in the fact that nuclear reactions sometimes take place in the atmospheres of stars, as has been studied observationally by us (*25*), and theoretically by W. A. Fowler and us (*26*). The energy source necessary to accelerate the reacting nuclei to high enough energies is electromagnetic. Although the sun has an average surface magnetic field of only about 1 gauss, sunspots have fields of several thousand gauss, and small localized high-temperature disturbances (flares), which appear to have the nature of discharge phenomena, sometimes occur. The so-called magnetic stars have average surface fields of 1000 to 10,000 gauss, and it is possible that localized areas on such stars might have even larger fields.

Since stellar atmospheres usually contain abundant hydrogen, the particles accelerated by the magnetic fields will mostly be protons. Interactions with light nuclei, for example, N^{14} (p,n)O^{14}, will free neutrons, which, in the presence of hydrogen, will almost all be captured by it in the first instance to form deuterium. In fact there is some evidence that deuterium is present in considerable quantities in solar flares (*27*).

The problem of understanding how nuclear reactions can take place in the atmosphere of a star is rather similar to the problem of understanding the conditions under which a plasma in the laboratory can be heated to such a degree that nuclear reactions take place—that is, the problem of controlled fusion. The main differences are that the star's atmosphere is a hydrogen plasma while in the laboratory a deuterium plasma is used, and, secondly, in the star we are interested in the synthesis that can occur, while the problem in the laboratory is that of getting the maximum energy release possible. In the laboratory there is much interest in force-free magnetic fields, while in the atmospheres of magnetic stars, since there is no evidence for any undue pressure effects despite the large fields, they may take up a force-free form, in some way that we do not yet understand.

If deuterium is made locally in magnetic stars, some of it may escape into the interstellar gas out of which new stars will be formed. We do not yet know what the deuterium concentration is in the interstellar gas, but if it is as high as it is on earth, it may soon be measured by radio-astronomical techniques, by means of the radiation at 327 megacycles per second, which is analogous to the 21-centimeter radiation from neutral atomic hydrogen in interstellar space.

Another possibility for the production of deuterium is that it might be made in the expanding shells of those supernovae whose envelopes still contain abundant hydrogen, if a flux of neutrons reaches the envelope. However, the large abundance of deuterium on the earth, if it turns out to be universal, may present some difficulty in either of these mechanisms. The suggestion was made earlier that possibly deuterium can be produced in the ylem if this type of cosmological model is correct, but this would mean that we would not have a *complete* stellar synthesis theory.

In the surfaces of magnetic stars, in an acceleration process, there will be a

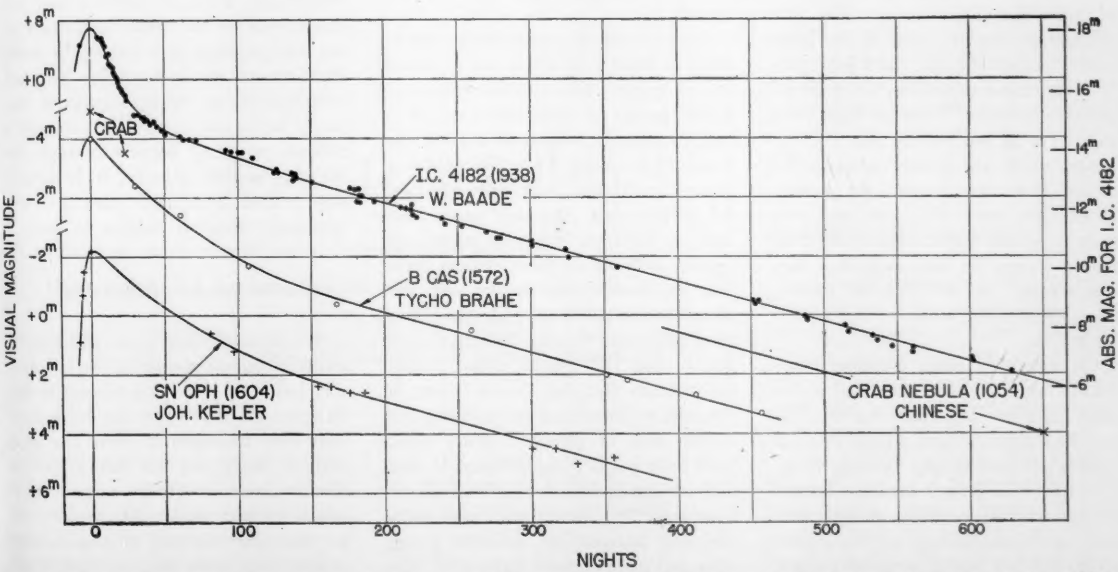

Fig. 10. Light curves of supernovae by Baade. Measures for the supernovae in IC 4182 are by Baade; those for B Cassiopeiae (1572) and SN Ophiuchi (1604) have been converted by him to the modern magnitude scale from the measures by Tycho Brahe and Kepler. The three points for the supernova of 1054 are uncertain, being taken from the ancient Chinese records. The abscissa gives the number of nights after maximum; the left-hand ordinate gives the apparent magnitude which is a logarithmic scale (separate scale for each curve); the points for the Crab Nebula belong on the middle scale—that is, that for B Cassiopeiae. The right-hand ordinate gives the absolute magnitude for SN IC 4182 derived by using the current distance scale. [Courtesy *Reviews of Modern Physics* (*19*)]

small fraction of the particles that will reach sufficiently high energies to break up heavier nuclei. In such break-up processes, lithium, beryllium, and boron are frequent products. It is not hard to account for the abundance of these elements by postulating their production and escape from the atmospheres of stars if magnetic activity, as seems probable, is widespread in the numerous red dwarfs on the main sequence below the sun. For the sake of completeness, we should mention that it is possible also that lithium is built under special conditions of mixing in certain red-giant stars.

Interchange of Matter between Stars and the Interstellar Medium

We have seen that the chemical evolution of the stars is a necessary consequence of their very existence. Thus the building of heavier elements from hydrogen must be continually going on inside stars. Whether this can account for the observed abundances of all of the elements is another matter, depending upon the *rate* of star formation and death, and upon the efficiency of the various ways in which matter, processed in stars, can return to the interstellar gas. It is impossible at present to make better than very sketchy and approximate computations of the balance between observed abundances and the rate of production of the elements. The most spectacular way of spreading the products of nuclear processes back into space is by supernova explosions, but these are not very common. There are apparently two types of supernovae, and the statistics, which are rather uncertain, indicate that they occur, per galaxy, about once every 300 years and once every 50 years, respectively. From these figures it can be estimated that they can account for the observed relative abundances of the α-, e-, r-, and p-process nuclei.

On the other hand, evidence is accumulating (*28*) that giant and supergiant stars steadily eject matter. This may be a more efficient process than explosive ejection simply because it involves a much greater number of stars. In this way the products of hydrogen-burning, helium-burning, and the *s*-process may be returned to interstellar space. Counts of the number of stars of a given brightness per unit volume of space, together with knowledge of how long a star of a particular brightness can last on the main sequence, enable one to estimate how many stars pass through a giant stage. Taking into account the fact that the rate of star births must have been greater in the early history of the galaxy than it is today, as we shall discuss in the next section, it has been calculated that in a time of order 10^{10} years there has been enough ejection to account for the observed abundances of the products of hydrogen-burning, helium-burning, and the *s*-process.

Thus the stellar synthesis theory can certainly account qualitatively, and can probably account quantitatively, for the observed abundances of all of the elements.

Evolution of Galaxies

During the life history of a galaxy there should be a steady enrichment in elements heavier than hydrogen. In an explosive cosmology combined with the stellar synthesis theory, a galaxy would consist at first of pure hydrogen, while in the steady-state cosmology it might have a small amount of heavier elements synthesized in other, earlier, galaxies. For either model, as time passes, the succeeding generations of stars should be formed out of interstellar gas and dust containing a successively richer admixture of elements heavier than hydrogen. The final stage in the history of a galaxy will be reached when it is made up completely of white dwarfs.

Evidence of the progressive enrichment in heavier elements can be found in our galaxy. The globular clusters—dense groups of stars that are in a roughly spherical distribution about the center of our galaxy—are the oldest star groups yet known, with ages of about 6.5 billion years. Although quantitative analyses have not yet been made, the spectra of some of these clusters show that the metals must be in very low abundance relative to hydrogen. Two stars quite near the sun, HD 19445 (see Fig. 6) and HD 140283, whose velocities indicate that they do not belong in the solar neighborhood but probably are closely akin to globular cluster stars, have been found to be deficient in iron and calcium by factors of 10 and 30, respectively (*29*). Some stars with compositions intermediate between young stars and these extreme cases have also been analyzed (*29*).

We may call this the aging effect. It is an effect that is quite apart from the individual chemical evolution of a particular star. The oldest groups of stars were formed out of material whose average composition was different from that today. The observations are hard to explain in any other way than by the stellar synthesis theory, but they are a necessary consequence of it. To account for the variety of processes needed to synthesize the elements in the solar system, the sun must be at least a third-generation star, although it is about 5 billion years old. Differences in composition between the sun and young stars are not very large. Possibly in the early history of the galaxy the rate of star formation and death was much faster than it is now, so that elements were synthesized and ejected more rapidly. This is borne out by the radio-astronomical evidence that the amount of gas (which will determine the rate of star formation) is at present only about 1 percent of the mass of our galaxy, while in the beginning it must have comprised 100 percent.

This raises the question of whether an evolutionary sequence can be detected among external galaxies. Those that have recently formed would be expected to contain more interstellar gas and less heavy elements than those that have been in existence a long time. The study of galactic evolution is in its infancy at present. We do not know whether the different structural forms —irregular (youngest), barred spiral, spiral, and elliptical (oldest)—represent evolutionary stages, or whether they are determined by the initial conditions at the time of birth of a galaxy, or both. Furthermore, the study of the chemical compositions of external galaxies has barely begun and must always remain a difficult problem, because, except for the very nearest galaxies, it is impossible to look at anything other than the integrated effect of billions of stars.

Conclusion: Problems Remaining

Astrophysical observations and experiments in nuclear physics in the last decade have lent increasing support to the idea that all of the elements have been built from hydrogen in stars. The next steps in developing this theory lead in several directions. Firstly, more experimental nuclear physics data are needed, in particular isotopic neutron-capture cross-sections, more accurate binding energies of nuclei in the range of $60 < A < 210$ (for improving the details of the r-process), and information on heavy-particle reactions (almost wholly lacking) and improved reactions rates among

the light nuclei. This is all basic information without which it will be hard to refine the nuclear physics of the problem.

On the side of theoretical astrophysics, models for stellar evolution need to be taken further, and the evolutionary path of a star after it leaves the red giant configuration must be understood. This involves computational programs on the best automatic computers, such as the one devised by Hoyle for an IBM 704. The problem of handling instabilities in the evolutionary path remains to be solved. On the observational side, more work on the determination of abundances in stars is needed. At present, there has been much qualitative examination of spectra but very little spectroscopic analysis to give quantitative results. More studies of old stars, preferably members of clusters that can actually be dated by the position of the break-off from the main sequence, will be very valuable.

Galactic evolution is one of the subjects where interesting new developments may come soon. This embraces study of the structures, spectra, and distribution of galaxies, as well as theoretical work. When it is remembered that so well-known a feature as the arms in spiral galaxies are still imperfectly understood theoretically, it will be seen how much work still remains to be done in this field.

Astrophysics is the only branch of physics in which we cannot make experiments, but can only observe. It is a science also in which the conditions are always more extreme than any attainable in terrestrial laboratories and the time scales are unimaginably longer. Perhaps its fascination lies in this very aspect, that it challenges man's imagination to the utmost.

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Long-Term Fallout

A summary of measurements made through June 1957 by the gummed-film network of the AEC is presented.

Merril Eisenbud and John H. Harley

Several papers have described the phenomena of long-range fallout and the methods by which it is routinely monitored (*1*). This paper presents estimates of strontium-90 deposition and external gamma dose which were obtained from the world-wide gummed film network of the U.S. Atomic Energy Commission through June 1957. Results for the continental United States and other stations are tabulated in Table 1; results for the worldwide network are mapped in Fig. 1. In addition, the estimates of strontium-90 deposition as obtained by the gummed-film method are compard with measured values obtained by sampling with open pots.

Because of their mass, it is not practical to present the detailed analytical results in this article (*2*). This presentation, therefore, is limited to a condensation of the cumulative fallout observations.

Sampling and Measurement

A primary technique in studying long-range fallout is the measurement of the rate of deposition and the cumulative deposit per unit area. For this purpose, three types of samples are currently used: soils, pots or funnels, and gummed film.

Soil samples represent the accumulated fallout at a given location, but these samples require tedious radiochemical analyses for the determination of specific isotopes. Moreover, soil sampling does not permit one to estimate the external gamma dose delivered by the isotopes because of difficulty in analysis and uncertainty in the time of fallout.

Open samplers, such as pots or fun-

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nels, permit collection of individual rainfalls or weekly or monthly deposits, from which strontium-90 and other isotopes may be determined directly by radiochemical analyses. Gamma emitters may be evaluated by spectroscopy.

The principal advantage of the gummed-film method, in addition to its simplicity, is that it permits daily sampling. This is important for the estimation of gamma dose.

There can be no absolute sampling procedure for fallout deposition because the deposition in a given situation will be influenced by the type of surface. However, to permit some basis of comparison, the collection performance of the gummed film has been studied in relation to the collection performance of pots.

In earlier reports, it has been shown that the gummed film, under conditions of moderate rainfall in a temperate climate, yields fallout samples with an overall efficiency of about 63 percent compared with the values from high-walled pots. In regions where much of the fallout occurs with snow, the gummed-film method may grossly underestimate the true fallout values. Despite this objection, the gummed-film technique has proved to be desirable because of the simplicity with which daily samples can be accumulated from a large number of widely scattered locations.

Since late 1954, the computation of strontium-90 from the total beta activity of the gummed-film samples has become increasingly difficult because the computed values are sensitive to the assumed age of the debris. The accumulation of long-lived fission products in the stratosphere and the greater frequency of weapon tests has greatly complicated the problem of assigning an age to the

Table 1. Strontium-90 deposition and cumulative gamma dose as estimated by gummed-film measurements through June 1957.

Station	Sr^{90} (mc/mi^2)	External γ dose (mrad)*
Outside continental United States		
Alaska		
Anchorage	12	20
Fairbanks	15	26
Juneau	16	30
Nome	9	17
Argentina		
Buenos Aires	9	18
Australia		
Sydney	6	17
Bermuda	21	43
Bolivia		
La Paz	9	22
Canada		
Churchill, Manitoba	6	11
Edmonton, Alberta	18	33
Goose Bay, Labrador	13	29
Moncton, New Brunswick	13	25
Montreal, Quebec	16	33
Moosoonee, Ontario	13	29
North Bay, Ontario	17	34
Ottawa, Ontario	12	25
Regina, Saskatchewan	13	27
Seven Islands, Quebec	12	27
Stephenville, Newfoundland	20	42
Winnepeg, Manitoba	23	45
Ceylon		
Colombo	9	29
Costa Rica		
San Jose	7	17
Ecuador		
Quito	5	14
Ethiopia		
Addis Ababa	11	21
French West Africa		
Dakar	12	22
Germany		
Rhein Main	15	27
Greenland		
Thule	9	15
Hawaii		
French Frigate Shoals	21	42
Lihue	18	38
Hilo	30	59
Honolulu	16	34
Iceland		
Keflavik	21	36
Italy		
Milan	13	23
Japan		
Hiroshima	19	36
Misawa	20	39
Nagasaki	21	41
Tokyo	23	43
Liberia		
Monrovia	10	19
Malaya		
Singapore	7	23
Mexico		
Mexico City	16	39
Morocco		
Sidi Slimane	18	30
New Zealand		
Wellington	5	10
Nigeria		
Lagos	8	14
Norway		
Oslo	13	23
Pacific Ocean		
Yap, Caroline Islands	17	52
Guam, Caroline Islands	78	160
Truk, Caroline Islands	33	87
Ponape, Caroline Islands	41	140
Canton Island	7	23
Iwo Jima	36	170
Johnston Island	30	65
Koror, Palau Island	14	44
Manila, Philippine Islands	17	48
Midway Island	19	36
Noumea, New Caledonia	8	20
Wake Island	22	45
Panama Canal Zone	9	22
Puerto Rico		
San Juan	15	29
Saudi Arabia		
Dhahran	15	28
Scotland		
Prestwick	18	30
Thailand		
Bangkok	10	39
Tripoli		
Libya	24	41
Union of South Africa		
Durban	4	8
Pretoria	10	19
Continental United States		
Albuquerque, N.M.	45	150
Atlanta, Ga.	20	41
Billings, Mont.	26	58
Binghamton, N.Y.	13	25
Boise, Idaho	27	44
Boston, Mass.	20	69
Cape Hatteras, N.C.	14	29
Chicago, Ill.	22	50
Cleveland, Ohio	25	65
Concord, N.H.	11	26
Corpus Christi, Tex.	12	25
Dallas, Tex.	25	60
Des Moines, Iowa	27	63
Detroit, Mich.	22	49
Grand Junction, Colo.	39	160
Jacksonville, Fla.	13	30
Knoxville, Tenn.	18	45
Las Vegas, Nev.	23	66
Los Angeles, Calif.	11	20
Louisville, Ky.	24	54
Medford, Oreg.	13	23
Memphis, Tenn.	24	75
Miami, Fla.	16	37
Minneapolis, Minn.	25	51
New Haven, Conn.	20	43
New Orleans, La.	28	64
New York, N.Y.	28	54
Philadelphia, Pa.	19	39
Pittsburgh, Pa.	26	46
Rapid City, S.D.	18	45
Rochester, N.Y.	19	37
Salt Lake City, Utah	54	180
San Francisco, Calif.	14	23
Scottsbluff, Neb.	38	73
Seattle, Wash.	19	34
Tucson, Ariz.	25	49
Washington, D.C.	18	35
Wichita, Kan.	25	62

* The tabulated values are calculated infinity exterial gamma dose in millirad. The probable exposure to the population, allowing for shielding and weathering, is approximately 10 percent of this value.

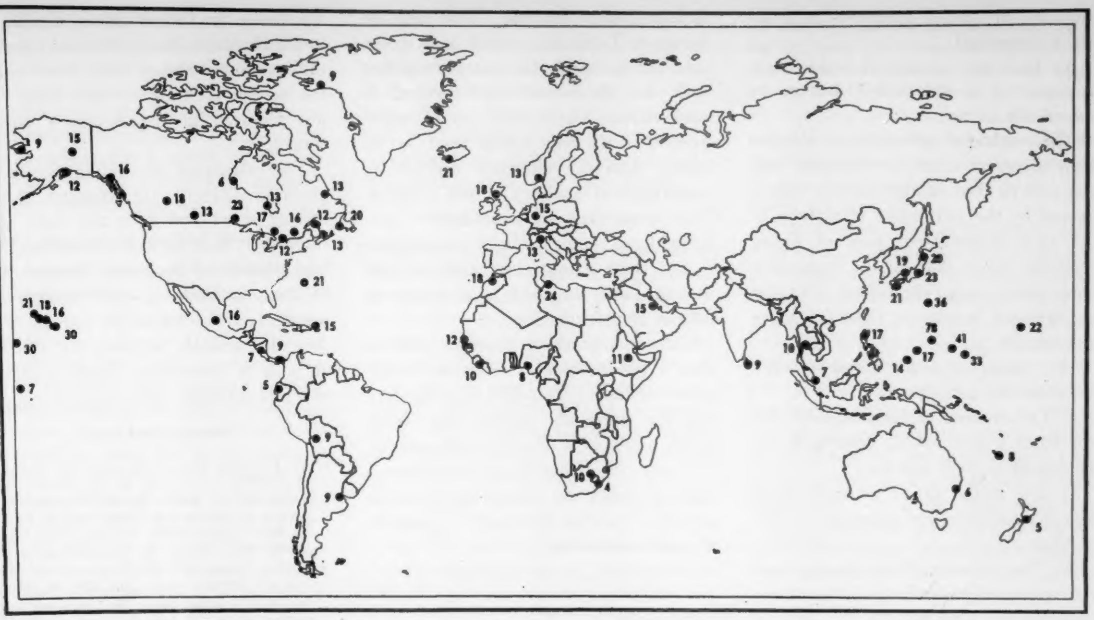

Fig. 1. Calculated cumulative strontium-90 fallout in millicuries per square mile as of June 1957.

debris. However, a method of computation has been devised by which the latter difficulty can be minimized.

Methods of Computation

The adhesive-coated films, which have been exposed for 24 hours, are shipped to the U.S. Atomic Energy Commission's Health and Safety Laboratory in New York. The total beta activity of the ashed samples is measured and corrected by the 63 percent efficiency factor. The strontium-90 component of the fallout is calculated from modified Hunter and Ballou (*3*) ratios. In addition, an estimate of the infinity external gamma dose in air is made from the beta activity (*4*).

The original calculations of strontium-90 deposition from measurements of total beta activity on ashed gummed-film samples were performed as follows:

1) The activity measured on a given sampling day was attributed to the test immediately preceding that sampling day.

2) The measured activity on the counting day was extrapolated to a fixed day by the formula

$$A = A_1 t^{-1.2}.$$

3) The strontium-90 fraction of the total beta activity on this day was taken from modified Hunter and Ballou curves.

4) The strontium-90 activity values for the individual days were summed by months, and these sums were added for the desired period of accumulation.

The assignment of activity on a given day to the most recent test was a reasonable approximation during the period of tropospheric fallout. The deviations between gummed-film estimates and radiochemical analyses became larger as the contribution from stratospheric fallout increased. To improve the estimation of strontium-90, a system was devised which takes stratospheric debris into account. Tests of this simplified model yielded values that are in good agreement with computations from more complex models. This method, which has been applied to data subsequent to May 1956, is as follows:

1) Estimates of the yields of total fission products and of strontium-90 are obtained for each weapon test.

2) The total fission-product yield for each test is added to the calculated fission-product residue from previous tests. (The $t^{-1.2}$ law is used for decaying total fission product activity.)

3) The strontium-90 activity from each test is added to the accumulated strontium-90 activity from previous tests.

4) For each sampling day, the stron-

Table 2. Comparison of strontium-90 estimates from gummed-film with radiochemical analysis of monthly pot collections.

Period of observation	Total Sr^{90} (mc/mi^2)		Ratio film/pot	Monthly ratios		Film/pot mean
	Film	Pots		Low	High	
		New York City				
5/56–6/57	12.3	13.7	0.90	0.32	2.2	1.1
		Pittsburgh				
5/56–6/57	12.1	10.6	1.14	0.62	2.5	1.2
		Chicago				
12/56–6/57	6.3	4.6	1.37	1.0	1.9	1.4
		Salt Lake City				
12/56–6/57	15.1	9.1	1.66	1.1	3.3	1.8
		Los Angeles				
12/56–6/57	3.5	3.1	1.13	0.78	2.4	1.4
		Hiroshima				
10/56–6/57	5.6	3.7	1.51	0.82	3.7	1.7
		Nagasaki				
8/56–6/57	6.7	5.5	1.22	0.64	5.5	1.6

tium-90/total-fission-product-activity ratio is calculated.

5) Each day's measured beta activity is converted to strontium-90 activity by use of this factor.

This method of calculation would give high strontium values for locations near test sites on days of high fallout. This is caused by the attribution of activity to the total accumulated pool of fission products rather than to the immediate burst which caused the fallout. This can be corrected by treating these few cases individually.

The major approximations of this technique are as follows:

1) Tropospheric and stratospheric debris enter a pool which contributes to the fallout at each location.

2) The mixed fission products from each detonation decay according to the $t^{-1.2}$ law.

3) The relative tropospheric and stratospheric depletion rates are not considered at this time.

The only practical means of evaluating the new calculation technique is by comparison with radiochemical analyses of open samplers. During the period from May 1956 to June 1957, several locations had parallel sampling units for at least part of the time. These data are shown in Table 2, in which it is shown that the gummed-film system, together with the above-mentioned method of computation, yields estimates of strontium-90 deposition which tend to be higher than the estimates derived by radiochemical analyses of pot samples. The mean ratio of strontium-90 estimated from gummed-film to pot analyses is 1.45, with a maximum ratio of 1.66 at Salt Lake City and a minimum of 0.90 in New York City.

The calculation of external gamma dose is less sensitive to variations in the source of fallout. In addition, it appears that the important gamma dose from fission products is from internal cesium-137 rather than from the external gamma radiation from distributed fission products after suitable allowance for shielding and weathering.

Conclusions

The range of values for strontium-90 deposition through June 1957 in the United States is 11 to 54 millicuries per square mile, which is somewhat higher than other large land areas of the world. Excluding the United States, deposition in the Northern Hemisphere averages 16 millicuries per square mile, about twice the average for the somewhat fewer values reported in the Southern Hemisphere.

The calculated external gamma doses given in Table 1 are estimates of the infinity doses and have not been corrected for shielding and weathering. Our best estimate of the actual external dose to the population is approximately 10 percent of the tabulated values. The dose may actually be lower, but a factor of 10 is a conservative estimate of the effect of shielding and weathering.

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News of Science

Excerpts from the Summary and Conclusions of the Report of the United Nations Scientific Committee on the Effects of Atomic Radiation

In estimating the possible hazards of ionizing radiation, it is clearly necessary to know both the levels of such radiation received by man and his environment from various sources, and the present and future effects likely to be produced thereby. It is of particular importance to assess the effects of radioactive fallout from nuclear weapons, since this source of general environmental contamination is of recent origin, has been of uncertain significance, and has led to concern in the minds of many people. All sources of radiation must, however, be reviewed for a complete evaluation of the situation.

The Committee, aware of the complexity of this task, knows that our present information about radiation levels and effects is inadequate for an accurate evaluation of all hazards, and that many of the estimates will necessarily be approximate or tentative.

The physical characteristics of ionizing radiation, and the amounts of human exposures to it, are at present more accurately known than its biological consequences, especially where small doses and dose rates are concerned. In the present chapter, therefore, we review first the amounts of radiation received by man, both in regard to the exposure of individuals and of whole populations, and in respect to present and possible future levels. We then attempt to estimate the biological effects of varying amounts of radiation of different types, and to evaluate the hazard resulting from certain sources of particular significance.

. . . In view of the complex nature of the subject, individual sentences or assessments may easily be misunderstood unless related to the context of the report as a whole. . . .

Radiation from Natural Sources

The radiation received by man from natural sources varies somewhat from place to place according to the local radioactivity of the earth's surface; and that of only occasional populated areas exceeds the average by a factor of 10. Studies on populations living in these areas are of extreme interest for the development of our knowledge on the effects of small doses of radiation. The contribution from cosmic rays differs at different altitudes and geomagnetic latitudes. That from the normal radioactive potassium and carbon content of the body is about the same in different people, but the radiation due to radium, thorium and their decay products varies

considerably. The radioactivity of the masonry used for some types of dwelling may appreciably increase the radiation exposure of the occupants. . . . Harmful effects attributable to radiation from natural sources are not known with any certainty, but it seems likely that some genetic, and possibly some somatic, injury is caused in this way.

Exposure Due to Medical Procedures

It is useful to estimate this exposure, appropriately averaged over whole populations, since the genetic, and perhaps some somatic, effects of these procedures will depend upon this average value. In the countries with extensive medical facilities where its magnitude has been estimated, the radiation given for medical purposes makes the largest artificial contribution to the irradiation of the population, but no data are available for countries with fewer such facilities. The reported values of genetically significant doses are of the same order as the doses from natural sources. Among medical procedures, the contribution from diagnostic X-ray examinations greatly exceeds that from radiotherapy and radioisotope applications, the latter making only a small contribution; and 80 to 90 percent of the total diagnostic dose to the gonads is due to relatively few types of examination of the abdomen and pelvis. . . .

The significant dose to bone and bone marrow from medical procedures has been less closely studied than the genetically significant dose, although it may be of importance if bone tumours or leukemia are induced by radiation at low dose levels. Although individual marrow exposures vary very widely, the average is unlikely to differ greatly from that received by the marrow from all natural sources.

. . . No information is yet available for prediction of the future trend of medical exposures. It is expected that improvements in equipment and techniques may considerably reduce individual exposures, but the ever-expanding use of X-rays may well increase the world population dose. . . .

Radiation from Occupations and Wastes

At present, the exposure to ionizing radiation received occupationally forms only a small contribution to the total irradiation of the population as a whole, amounting to about 2 percent of that from natural sources in countries in which occupational exposure is probably largest. With an increasing use of nuclear reactors, of radioactive materials and probably of medical and industrial radiological procedures, this is clearly a figure which should be kept under close review. . . .

The discharge of radioactive waste in countries with nuclear reactors has not led to appreciable radiation exposure of populations, and only small proportions of the wastes produced need to be discharged. . . . [However,] it is important that work should be actively continued on methods of minimizing environmental contamination from these causes.

Radiation from Fall-out

Fall-out from nuclear weapon tests causes radiation exposure in several ways. Exposure of the world population results from the slow fall-out of fission products which have been distributed in the stratosphere. Exposures also result from any fall-out from the radioactive "cloud" which passes through the troposphere without having reached the higher stratosphere, and from the fall-out which may occur in areas adjacent to weapon tests or within some thousand kilometres of them.

We also consider the ways in which fall-out material causes irradiation to different parts of the body, to people on different diets or under different agricultural conditions, and to people of different ages; and the change in the amounts of radiation that would result from altered or unaltered rates of injection of radioactive materials into the stratosphere.

Adjacent to tests. The early fall-out of radioactive materials near to the sites of nuclear explosions, which is influenced by various meteorological and testing conditions, may cause high radiation exposure to individuals within these areas. The amount of such radiation exposures varies very greatly with the weapon tested, with the height of firing, with the distance from the point of explosion, with the direction of winds at various altitudes and with the chance occurrence of rainfall through radioactive material in the early hours after the test. Therefore, at present, these doses cannot in general be calculated. Under very special conditions, high radiation exposure and deleterious effects have been reported, as in the cases of the Marshall Islanders and the crew of a Japanese fishing vessel. Not enough information is available as to the general circumstances in which such local deposition may occur, and the extent and duration of the exposures liable to be involved.

From the troposphere. Radioactive materials injected into the atmosphere below the tropopause (at about 14 km) are brought down to the earth's surface by rainfall and sedimentation. This process takes a few months during which they are carried several times around the world. This tropospheric fall-out consists of a mixture of radioactive materials, most of which are short-lived isotopes. At the present time, the tropospheric fall-out is deposited intermittently during the year and a certain deposit of short-lived activities is built up and maintained. When appropriate factors for shielding and weathering effects are included, the gonad and average marrow dose from this deposit, as an external source, is calculated to be about 0.5 mrem per year.

Transient increases of the doses from tropospheric fall-out have been observed in limited areas shortly after weapon tests. These transient increases may give rise for a few days to dose rates of the order of those from natural sources.

The radioisotopes of tropospheric fall-out may be taken up into the body by inhalation and ingestion. Since the radioisotopes of principal concern are short-lived, storage of the contaminated food products reduces the dose which they contribute. The gonad dose over the whole population from inhaled and ingested tropospheric material is negligible as compared with the contribution from this material as an external source. The average bone marrow dose from internal sources is about 0.2 mrem per year.

Increases in radioactivity of the thyroid gland have been found during periods of several weeks or a few months following weapon tests. In human thyroids a dose from iodine-131 of about 5 mrem per year has been estimated for 1955–1956 in the United States excluding areas immediately adjacent to weapon test sites. Doses of this order are unlikely to cause detectable damage or functional change in the gland.

Irradiation of bone may result from incorporation of intermediate and short-lived fission products. Although these materials do not cause prolonged irradiation, they may become selectively concentrated into those areas of bone in which active growth is taking place at the time, and so cause more intense radiation locally than if the same amounts of these materials were distributed throughout the whole skeleton.

The Committee has insufficient information on local variations and temporary increases of tropospheric fall-out in populated areas at different distances from weapon test sites, and emphasizes the lack of further data which would permit evaluation of the biological significance of this source of environmental contamination.

From the stratosphere. Radioactive materials injected into the stratosphere, especially by high-yield nuclear explosions, constitute a reservoir from which they fall onto the whole of the earth's surface for many years. The rate of fall-out varies with latitude and is greater in the northern hemisphere, where most of the tests are carried out. Within any given small area, fall-out rate may also vary with local meteorological condi-

tions. . . . The radiation due to stratospheric fall-out from weapons exploded so far will contribute a 30-year gonad dose of 10 mrem, and a 70-year *per capita* mean marrow dose of 160 mrem and 960 mrem for two populations deriving most of their dietary calcium from milk and rice respectively.

Owing to the relatively gradual fall-out from the stratosphere, most of the subsequent radiation is due to two radioactive isotopes of slow decay, other fission products already having largely undergone decay. These two radioactive isotopes are caesium-137 and strontium-90. The physical properties and chemical behaviour of the two differ.

. . . When [caesium-137] is taken into the body, it becomes distributed more or less evenly throughout the tissues, causing uniform irradiation of the whole body; and when present in the surroundings, its penetrating gamma radiations cause a similarly uniform irradiation of tissues.

Strontium-90, on the other hand, is not a gamma-emitter and does not contribute significantly to the irradiation of any part of the body from without. However, on being taken into the body, it becomes incorporated in bone because of its chemical similarity to the normal bone-forming element calcium. This similarity with calcium and selective concentration in bone raises problems which do not occur with caesium-137.

The average concentration of strontium-90 in the bones of children, in whom new bone is continuously being formed, is higher than in adults whose bones were largely formed before the environment, and consequently the food supply, became contaminated with strontium-90. . . .

The radiostrontium concentration in bone is also affected by dietary habit and by the ratio of the amounts of strontium-90 to calcium in the diet. . . .

Agricultural conditions may also affect the content of strontium-90 in the diet, since the available calcium of the soil will, within certain limits, influence the ratio of strontium-90 to calcium in crops derived from the soil. . . .

Biological Effects of Radiation

The biological effects of ionizing radiation are exhibited in different ways according to whether isolated cells, tissues, organs, or organisms are examined. In passing from unicellular to higher organisms, the primary physicochemical consequences of radiation become increasingly influenced by secondary effects due to the reactions of the organism to the primary events. Detailed knowledge of these reactions is needed for a full understanding of the results and mode of action of radiation. . . .

The effects of ionizing radiations on living matter . . . are still largely unknown. The initial disturbance is associated with ionization (and excitation) of molecules which lead to alterations in their properties. Many functions of the cell are thus affected by radiation, and, although some specific effects may be caused by one or a few events in the cell, many are probably the combined result of numerous such events.

The minimum doses causing certain detectable biological effects differ very much in different organisms, but for most mammals they are about the same magnitude, so that the results of experiments on such animals can, as a first approximation, be applied to man. The sensitivity of different tissues to radiation varies considerably, however. Our knowledge of the biological effects of low radiation levels is meagre because of experimental difficulties and the lengthy observations necessary to obtain results in this field. At present, opinions as to the possible effects of low radiation levels must be based only on extrapolations from experience with high doses and dose rates.

Effects of Radiations on Man

Man may prove to be unusually vulnerable to ionizing radiations, including continuous exposure at low levels, on account of his known sensitivity to radiation, his long life, and the long interval between conception and the end of the period of reproduction.

Embryonic cells are especially sensitive to radiation, and some evidence suggests that exposure of the foetus to small doses of radiation may result in leukemia during childhood. Irradiation of pregnant mammals has shown that doses exceeding 25 rem to the foetus during certain stages of its development can cause abnormalities in some organs. Some embryonic cells (neuroblasts) of certain species cultivated *in vitro* respond to doses as small as 1 rad. If these results should be applicable to man and since they relate to the development of the brain, the opinion seems justified that even a very small dose to the human foetus may involve some risk of injurious effects if received during a critical period of pregnancy. Radiostrontium must be expected to enter foetal bone when calcification starts in the second trimester of pregnancy, and so cause irradiation of the adjacent developing nervous system and hypophysis with exposures ranging up to that occurring in the bone. The uptake of radiostrontium in foetal bone tissue is, however, at present very small, contributing less radiation than 1 percent of that due to natural sources; but if the present rate of test explosions is continued, it will rise ultimately to some 10 percent of that due to natural sources.

Children are regarded as being more sensitive to radiation than adults, although there is little direct evidence on this subject, except for an indication that cancer of the thyroid may result from doses of a few hundred rad which do not induce this change in adults.

In human adults it is difficult to detect the effect of a single exposure to less than 25 to 50 rem, or of continuing exposure to levels below 100 times the natural levels. The first sign of radiation damage to the bloodforming tissues seems to be a drop in the number of lymphocytes and platelets and the appearance of abnormalities such as bilobed lymphocytes.

Rapid but transient disturbances have been observed in mammals after exposure to a single dose of 25 to 200 mrem. Appropriate biochemical and physiological techniques have, however, only recently been applied to the study of irradiated organisms, and have not yet given a clear picture of what happens to organisms irradiated with small doses or dose rates. Too few mammalian species have hitherto been studied in this respect, and there is a clear need to widen this basis, from which inferences can be drawn concerning man.

Processes of repair play an important role in the final outcome of radiation damage. They are one cause of the existence of a threshold dose (or dose rate) characterized by the fact that this dose or greater ones produce a particular biological effect which does not appear when the dose is less than the threshold. In the latter case, physicochemical events have occurred, but recovery processes have prevented the final appearance of the biological damage. Threshold doses are found for some somatic effects, such as erythema of skin. Other forms of radiation damage to cells, tissues or organisms, however, appear to be cumulative; for instance, mutational damage, once established, is not repaired.

Damaged cells or tissues may be eliminated and replaced by regenerated normal cells, this process being most active in embryos and young animals and in certain tissues of the adult. The affected cells may also re-establish apparently normal biochemical functions. During the process of regeneration of tissues damaged by radiation, malignant tumours may be induced.

The power of repair differs considerably in different organisms and types of cells, and varies to a high degree with the physiological conditions. No chemical treatment has yet been discovered which will induce or accelerate recovery from radiation damage to man. The grafting of blood-forming tissue has so far been successful only in small mammals irradiated with a lethal dose to

the whole body, and no attempt to apply this treatment to irradiated man has yet been reported.

Prevention of the effects of radiation is rendered more difficult, and complete protection against it impossible, because changes which already occur during the irradiation lead to later damage. The discovery of chemical protectors, although important theoretically, has not yet yielded methods which appreciably reduce radiation damage to man. At present, effective protection from external radiation sources can only be achieved by adequate shielding or by keeping at a safe distance from the source. Much work is in progress on the effect of certain (chelating) agents in discharging from the body radioisotopes incorporated there, and so diminishing exposure to internal irradiation.

Morphologically recognizable damage may be induced by total or partial, continuous or intermittent irradiations much in excess of the currently accepted "maximum permissible levels" of occupational exposure. Such damage includes leucopenia, anemia and leukemia. Other pathological conditions such as cataract, carcinoma of the thyroid, and bone sarcoma are known to have resulted from partial body irradiations, but with rather high doses involving hundreds or even thousands of rem given to these organs.

The shortening of the life-span in small rodents exposed to large doses has suggested the possibility that certain degenerative processes may be aggravated by continued exposure to low radiation levels. Such a shortening has also been inferred from an analysis of the published death rates of United States radiologists compared with those of certain other groups of medical men. However, studies in the United Kingdom have failed to demonstrate such an effect.

Present uncertainty about the effects of low dose levels makes it imperative that as much relevant information as possible be collected about groups of persons chronically exposed at these levels and for whom adequate control groups exist, for instance, certain populations in areas of high natural radiation and workers in uranium mines.

Exposure of gonads to even the smallest doses of ionizing radiations can give rise to mutant genes which accumulate, are transmissible to the progeny and are considered to be, in general, harmful to the human race. As the persons who will be affected will belong to future generations, it is important to minimize undue exposures of populations to such radiation and so to safeguard the well-being of those who are still unborn.

The present assumption of the strictly cumulative effect of radiation in inducing mutations in man is based upon some theoretical considerations and a limited amount of experimental data obtained by exposure of experimental organisms to relatively high dose levels. This assumption underlies all present assessments of the mutational consequences of irradiation. Therefore, extension of the experimental data to the lowest practicable dose levels is needed.

The knowledge that man's actions can impair his genetic inheritance, and the cumulative effect of ionizing radiation in causing such impairment, clearly emphasize the responsibilities of the present generation, particularly in view of the social consequences laid on human populations by unfavourable genes.

Besides increasing the incidence of easily discernible disorders, many of them serious but each comparatively rare, increased mutation may affect certain universal and important "biometrical" characters such as intelligence or life-span. In this way, it is possible that continued small genetically significant exposures of a population may affect, not only a correspondingly small number of individuals seriously, but also most of its members to a correspondingly small extent. While less easy to detect, this second kind of effect on a population could also be serious. Unfortunately, the great majority of the genes affecting the "biometrical" characters are not individually detectable and so can only be studied collectively and with difficulty. In consequence, far less is known about them than about genes responsible for individually detectable changes and very little indeed about their response to irradiation, even in the best studied experimental organisms. Hence it is impossible, at the present time, to estimate with any assurance the effect upon biometrical characters of any given level of irradiation of human populations. Much further research throughout this field is therefore needed.

The Committee emphasizes the urgent necessity for well-planned investigations which may lead to a better understanding of the mechanism of mutation and the eventual possibility of controlling this process. More information is needed on the effect of radiation in inducing mutations in man. Indeed, even the dose required to double the normal mutation rate in man is not known with any accuracy. There is also need for a much closer cooperation between geneticists and demographers in elucidating the nature of the complex process of human selection. . . .

General Conclusions

The exposure of mankind to ionizing radiation at present arises mainly from natural sources, from medical and industrial procedures, and from environmental contamination due to nuclear explosions. The industrial, research and medical applications expose only part of the population while natural sources and environmental sources expose the whole population. The artificial sources to which man is exposed during his work in industry and in scientific research are of value in science and technology. Their use is controllable, and exposures can be reduced by perfecting protection and safety techniques. All applications of X-ray and radioactive isotopes used in medicine for diagnostic purposes and for radiation therapy are for the benefit of mankind and can be controlled. Radioactive contamination of the environment resulting from explosions of nuclear weapons constitutes a growing increment to world-wide radiation levels. This involves new and largely unknown hazards to present and future populations; these hazards, by their very nature, are beyond the control of the exposed persons. The Committee concludes that all steps designed to minimize irradiation of human populations will act to the benefit of human health. Such steps include the avoidance of unnecessary exposure resulting from medical, industrial and other procedures for peaceful uses on the one hand and the cessation of contamination of the environment by explosions of nuclear weapons on the other. The Committee is aware that considerations involving effective control of all these sources of radiation involve national and international decisions which lie outside the scope of its work.

Certain general conclusions emerge clearly from the foregoing part of this report:

(a) Even the smallest amounts of radiation are liable to cause deleterious genetic, and perhaps also somatic, effects.

(b) Both natural radiation and radiation from fall-out involve the whole world population to a greater or lesser extent, whereas only a fraction of the population receive medical or occupational exposure. However, the irradiation of any groups of people, before and during the reproductive age, will contribute genetic effects to whole populations in so far as the gonads are exposed.

(c) Because of the delay with which the somatic effects of radiation may appear, and with which its genetic effects may be manifested, the full extent of the damage is not immediately apparent. It is, therefore, important to consider the speed with which levels of exposure could be altered by human action.

It is clear that medical and occupational exposure, and the testing of nuclear weapons, can be influenced by human action, and that natural radiation and the fall-out of radioactive material already injected into the stratosphere cannot.

. . . Many effects of irradiation are delayed. . . . Even a slow rise in the en-

vironmental radioactivity in the world, whether from weapon tests or any other sources, might eventually cause appreciable damage to large populations before it could be definitely identified as due to irradiation. . . .

Any present attempt to evaluate the effects of sources of radiation to which the world population is exposed can produce only tentative estimates with wide margins of uncertainty.

Fetal Anoxia

A team of six doctors from five medical schools will go to the Peruvian Andes this fall for special studies of pregnancy at very high altitudes. The expedition, financed by a grant from the Josiah Macy, Jr. Foundation, will be headed by Donald H. Barron of the Yale University School of Medicine and will include William Huckabee of the Boston University Medical School, Harry Prystowsky of the University of Florida Medical School, Andre Hellegers of the Johns Hopkins Medical School, Giacoma Meschia of the Yale University School of Medicine, and James Metcalfe of the Harvard Medical School. These men will conduct their investigations at the institute of Andean Biology in Morochocha, 15,000 feet above sea level. Alberto Hurtado (Harvard Medical School, '24), director of the institute and dean of the Medical School of the National University of San Marcos, Peru, will work with the group. Hurtado is an authority on high altitude studies.

In Peru, 63 percent of the population live at an altitude of 6000 feet or higher and 42 percent live at altitudes above 9000 feet. In contrast, only 1 percent of the population in the United States live at an altitude as high as 6000 feet.

The greatest single cause of mortality among infants at or about the time of birth is fetal anoxia. The six scientists hope to gain a better understanding of this problem from the Peruvian studies. The team will return to the United States in mid-November.

Technical Information Center

A Foreign Technical Information Center is now operating in the U.S. Department of Commerce to provide American science and industry with access to translations of a large amount of Soviet technical information. The center is a part of the Office of Technical Services, Business and Defense Administration.

The services of the new center include publication of abstracts of all articles appearing in 141 Soviet technical journals, translations of important sections of *Referativnyi Zhurnal* (the Russians' own abstract journal), and a semimonthly review of various areas of Soviet science compiled by the Central Intelligence Agency. Abstracts of each issue of the 141 journals may be purchased from OTS on a subscription or single-issue basis, as may CIA's *Scientific Information Report*. The various sections of *Referativnyi Zhurnal* will be sold initially by single issues, but subscription sales may be offered later.

The Office of Technical Services, which is directed by John C. Green, will soon begin distributing complete translations of articles and books. Translations will be listed in an abstract journal to begin publication about September.

Much of the material collected by OTS will be from government sources, principally the intelligence agencies. This volume is estimated to run at 50,000 abstracts and 10,000 complete translations a year. Eventually, material from other sources is expected to be added to the collection. Congress appropriated $510,000 for the operation of the foreign technical information program in fiscal 1959.

Atmosphere and Space

An International Conference on Physics and Medicine of the Atmosphere and Space will be held 10–12 November in San Antonio, Tex., under the sponsorship of the U.S. Air Force School of Aviation Medicine. Participants will include Hugh L. Dryden, director of the National Advisory Committee of Aeronautics, nucleus of this country's new civilian space agency; Joseph Kaplan, physicist from the University of California at Los Angeles who heads the U.S. National Committee for the International Geophysical Year; Fred L. Whipple, director of the Smithsonian Astrophysical Observatory; James A. Van Allen of the University of Iowa, specialist in rockets for high-altitude research; and Gerard P. Kuiper, astronomer at the University of Chicago.

Arrangements for the meeting are being conducted by the Southwest Research Institute. Because of limited facilities, attendance will be restricted to 500 on an invitational basis. For information write to the Southwest Research Center, 331 Gunter Building, San Antonio, Tex.

Fallout on Japanese IGY Ships

Japan has decided not to send out any more ships for International Geophysical Year oceanographic surveys until the United States suspends nuclear testing in the Pacific. Kanji Suda, chief of the Hydrographic Section of the Maritime Safety Agency announced the suspension after the *Satsuma* and the *Takuyo* ran into radioactive rain and sea water on 14 July following a United States nuclear explosion.

The ships have reported that their positions were well outside the danger zone established by the U.S. Atomic Energy Commission. Suda reported that IGY surveys of sea currents near the equator and of other phenomena were "completely spoiled" by the fallout hazard. The ill crew members of the two vessels have been examined by American and Japanese medical teams, both of which report that the men are unharmed.

Teacher Exchange

More than 600 teachers from the United States and 42 other countries will take part in the 1958–59 teacher exchange program. Arranged by the Office of Education, Department of Health, Education, and Welfare, the program is part of the United States international educational exchange program of the Department of State. With this year's exchange, nearly 5000 teachers from the United States and 64 other countries will have participated in the program, which is now in its 13th year.

One hundred American teachers from 26 States have left the country to exchange positions with 100 teachers from the United Kingdom. Among the countries participating in this year's program are Australia, Austria, Belgium, Canada, Chile, Colombia, Cuba, France, Germany, Italy, the Netherlands, New Zealand, and Norway.

Bykov Comments on U.S. Visit

Konstantin Bykov, Soviet physiologist and academician, recently visited the United States to attend the annual conference of the American Psychiatric Association in San Francisco and the Congress of the International Society of Gastroenterology held in Washington. Following his return to the U.S.S.R. Bykov made the following statement:

"My trip to America, which made it possible for me to get a comparatively good knowledge of the work being conducted by a number of research institutes and educational establishments there, was very fruitful. . . . The scientific meetings I went to and the visits I paid to research institutions enabled me to come to the conclusion that American psychiatrists and physiologists are conducting their scientific work on an extensive scale. It gives me pleasure to be able to say that the teaching of our great Russian scientist, Academician

Ivan Pavlov, on higher nervous activity is extremely widely supported in America. . . ."

Bykov reported that "American scientists are successfully working on the problems of the physiology of higher nervous activity." He particularly mentioned the work done by H. W. Magoun of the University of California, Los Angeles, on the role of the reticular formation of the brain. He also commented on the "extremely interesting work" that is being done by William H. Gantt of the Pavlovian Laboratory at the Johns Hopkins University School of Medicine in Baltimore.

"I was very pleased to see," Bykov said in conclusion, "that American scientists quite agree with us about the necessity of consolidating scientific links, of jointly working on various questions and exchanging information on our practical experience. I should like to express my sincere gratitude to my American colleagues for their great hospitality, and for the cordiality with which I was received during my stay in America."

Proposed Legislation

Of the many bills introduced in Congress, some have a special relevance to science and education. A list of such bills recently introduced follows:

HR 12784. Protect public health by amending Federal Food, Drug, and Cosmetic Act to prohibit use in food of chemical additives which have not been adequately tested to establish their safety. Osmers (R-N.J.). House Interstate and Foreign Commerce.

HR 7454. Amend the Tariff Act of 1930 to provide for free importation by colleges and universities of sound recordings and film to be used by them in certain nonprofit radio and television broadcasts. Eberharter (D-Pa.). House Ways and Means.

H Res 556. Express sense of House of Representatives in favor of continued testing by U.S. of nuclear and thermonuclear devices. Hillings (R-Calif.). Joint Committee on Atomic Energy.

News Briefs

A handbook for physicians who must treat victims of serious radiation is being compiled by the department of radiology and the radioisotope laboratory of the College of Medicine at the University of Cincinnati. The compilation, which was requested by the Atomic Energy Commission, is being done in cooperation with the commission's division of biology and medicine. A $5600 2-year grant supports the work.

The handbook will outline possible accidents, such as wreckage of a shipment of radioactive waste in transit, exposure to radioisotopes, sealed sources, x-ray generators, and so forth. It will list emergency procedure for exposed humans and the accident area, and guide the collection of data to be used in preparation for future accidents.

* * *

On 18 July the Congress voted $52,419,000 for the operation of the National Institute of Mental Health during the coming year. This is approximately $15 million more than the sum originally proposed by the Administration in January of this year.

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A postgraduate course on the pathology of diseases of laboratory animals will be conducted at the Armed Forces Institute of Pathology, Washington, D.C., 8–12 December 1958. The course is designed to provide training for professional officers who are responsible for the recognition and interpretation of lesions of experimental animals, or who have charge of procurement and maintenance of animal colonies. A limited number of spaces are available for civilian veterinarians. Applications for enrollment should be addressed to the Director, Armed Forces Institute of Pathology, Washington 25, D.C.

* * *

The American Institute of Physics Placement Service will collect information about graduate assistantships and fellowships for 1959–60 early in the fall of 1958 and make available the results the first of the new year. Chairmen of physics departments are asked to cooperate by filling in a questionnaire and returning it promptly to the institute at 335 E. 45 St., New York 17, N.Y.

Grants, Fellowships and Awards

Earth Sciences. The National Science Foundation is now receiving proposals for research grants that will be made in February and March, 1959. Deadline for the receipt of proposals for work to begin in the spring or early summer is *15 September 1958.* There are no formal application blanks, but a foundation pamphlet describes the method of making application and outlines information needed in a proposal. This pamphlet may be obtained by writing directly to the Earth Sciences Program, National Science Foundation, Washington 25, D.C.

Psychiatry. The Foundations' Fund for Research in Psychiatry has announced that *15 October* is the next deadline for the submission of completed applications for research fellowships in psychiatry, psychology, sociology, neurophysiology, and other sciences relevant to mental health. The deadline following this will be 15 January 1959.

The next deadline for receipt of applications for research grants-in-aid is *10 December.* For information write to: Foundations' Fund for Research in Psychiatry, 251 Edwards St., New Haven 11, Conn.

Announcement has been made of the Opportunity Fellowships for 1959–60 of the John Hay Whitney Foundation. The purpose of the fellowships is "To broaden opportunities in America. Specifically to give opportunity for special experience or advanced study to outstanding individuals who otherwise might not be able to reach their fullest development or make their fullest contribution." Deadline for filing is *30 November.* Address inquiries to: Opportunity Fellowships, John Hay Whitney Foundation, 630 Fifth Ave., New York 20, N.Y.

Scientists in the News

EDWARD L. HAENISCH is on leave from his position as chairman of the chemistry department at Wabash College to serve the National Science Foundation as program director for academic-year institutes, Division of Scientific Personnel and Education. He is also acting as director of the foundation's summer institutes program.

HEINZ GRUNZE, specialist in lung cytology and cochairman of the department of medicine at the Free University of West Berlin, Germany, will join the medical staff of the University of Chicago on 1 September 1958 as a visiting lecturer and research scholar. While he is in this country Grunze also plans to complete arrangements for the English translation of his book, *Klinische Zytologie der Thoraxkrankheiten.*

MARCUS M. RHOADES, professor of botany and cytogenetics at the University of Illinois, has been named head of the Indiana University department of botany. In September he will succeed RALPH E. CLELAND, who recently reached the compulsory retirement age for department heads and is now devoting his time to teaching and research. Rhoades is internationally known for his work on corn genetics.

The American Public Health Association, New York, has announced appointments to five newly created staff positions. The new appointees are THOMAS HOOD, associate executive director; JAMES L. TROUPIN, associate director assigned to the association's committee on professional education; NOBLE SWEARINGEN, director of

the Washington office; ROBERT MYTINGER, director of the western regional office in San Francisco; and EDWARD WELLIN, who will study the relation between public health and the behavioral sciences.

Wellin has been a research associate at the Harvard School of Public Health. Mytinger was formerly secretary of the public health committee of the Paper Cup and Container Institute, New York. Swearingen has been chief of the legislative unit of the National Tuberculosis Association. Troupin has been associated with the World Health Organization, and Hood was executive secretary of the Kansas State Board of Health.

A new department, agricultural biochemistry, will be established this fall at the University of California, Davis. It will be housed in the new soils and plant nutrition building, now under construction. PAUL K. STUMPF, professor of plant biochemistry and chairman of the department, will move to Davis from the Berkeley campus on 1 September, along with ERIC E. CONN, associate professor of plant biochemistry at Berkeley.

A. C. ALLISON, member of the British Medical Research Council's staff at the National Institute for Medical Research, London, will attend the International Congress of Genetics in Montreal, 20–27 August. His itinerary includes Alaska; Lawrence, Kan.; Seattle, Wash.; and Washington, D.C.

R. L. BROWN, director of the Basic Research Laboratories, British Coal Utilisation Research Association, Leatherhead, Surrey, England, will be in the United States and Canada from 5 September to 1 October. After attending the World Power Conference in Montreal, 5–11 September, he will visit Ottawa; Milwaukee, Wis.; Urbana, Ill.; Buffalo, N.Y.; Alliance and Columbus, Ohio; Pittsburgh, Pa.; Washington, D.C.; and New York.

Another visitor to this country is B. M. SLIZYNSKI, member of the Medical Research Council's external staff at the Institute of Animal Genetics, Edinburgh, Scotland. He is spending approximately 2 months working at the Cold Spring Harbor Biological Laboratory and at the Institute of Cancer Research, Philadelphia. While here he will attend the International Congress of Genetics in Montreal. He will work at Cold Spring Harbor before the conference and at Philadelphia following it.

JAMES BAILEY, consulting engineer for the Plax Corporation of Hartford, Conn., PRICE C. McLEMORE, a plantation owner of Montgomery, Ala., and GEORGE S. CRAMPTON, professor emeritus of ophthalmology at the University of Pennsylvania Medical School, will receive Edward Longstreth medals from the Franklin Institute, Philadelphia, on 15 October. Bailey developed the plastic bottle, McLemore invented the flame-weeding process for cotton, and Crampton invented the borescope, a specialized periscope for the internal inspection of turbine shafts and various closed vessels.

AARON NOVICK, associate professor of microbiology at the University of Chicago, has been appointed professor of biology and director of the new Institute of Molecular Biology at the University of Oregon, Eugene, effective 1 January 1959.

F. DOW SMITH has resigned as chairman of the department of physics at Boston University to accept a position as director of the Physical Research Laboratories of ITEK Corporation. ROBERT S. COHEN has been appointed acting chairman of the department.

Also in the physics department, MAX JAMMER of the Hebrew University in Jerusalem has been appointed visiting professor for the academic year 1958–59.

ELIJAH ADAMS, formerly associate professor of pharmacology at the New York University College of Medicine, has assumed the post of professor of pharmacology and director of the department at the Saint Louis University School of Medicine.

LEO ZIPPIN, a member of the Queens College faculty since 1938, has been named professor of mathematics at Yeshiva University's newly created Graduate School of Mathematics. Zippin has been serving this year as a visiting professor at Columbia University.

SARA E. BRANHAM, internationally known bacteriologist, has retired from the Public Health Service's medical research center at the National Institutes of Health. Since the creation of the Division of Biologics Standards in 1955, Dr. Branham has served as chief of the division's section on bacterial toxins. During the past year, she has been concerned with the study of the components of diphtheria toxin and presented some of her work in this field at the 7th International Congress for Microbiology in Stockholm, Sweden.

For the past 30 years, Dr. Branham has been engaged in microbiological research for the Public Health Service. Specialist in the meningococcus, she has demonstrated the epidemiological differences in groups of meningococci and has played a major role in the development of the current classification of these micro-organisms. With the advent of the sulfonamides, Dr. Branham was one of the first to study the susceptibility of various micro-organisms to these drugs. She has also devoted special attention to the toxin produced by the Shiga type of dysentery bacillus.

Dr. Branham received A.B. degrees from both Wesleyan College and the University of Colorado, and her M.D. and Ph.D. degrees from the University of Chicago. She was the recipient of the first outstanding achievement award to be given by the Wesleyan College Alumnae Association, and in 1952 received a distinguished service award from the University of Chicago Medical School Alumni Association. She also holds an honorary Sc.D. from the University of Colorado.

Recent Deaths

ANDREW E. BRYANS, West Townshend, Vt.; 65; professor of mathematics at Adelphi College in Garden City, N.Y.; formerly taught at Franklin and Marshall College; 26 July.

W. HALE CHARCH, Wilmington, Del.; 60; director of the Pioneering Research Laboratory of E. I. Du Pont de Nemours and Company; directed research that led to the development of moistureproof cellophane and various synthetic fibers, such as Orlon and Dacron; 13 July.

SAMUEL H. FLOWERMAN, New York, N.Y.; 46; supervising psychologist at the Postgraduate Center for Psychotherapy, New York, and former director of the department of scientific research of the American Jewish Committee; had been visiting professor at Columbia University and Rutgers University; coauthor of *Studies in Prejudice*; 29 July.

GREENHOW JOHNSTON, Richmond, Va.; 70; pioneer aeronautical engineer; 27 July.

HARRY D. LEINOFF, New York, N.Y.; 53; associate professor of medicine at New York Medical College; specialist in medicolegal jurisprudence; 21 July.

RALPH A. VAN METER, Harwich, Mass.; 64; president emeritus of the University of Massachusetts; dean of the School of Horticulture from 1931 to 1948; was professor of pomology for 25 years; 26 July.

Erratum: In the 1 August issue [*Science* 128, 24 (1958)] it was erroneously reported that Richmond K. Anderson of the Rockefeller Foundation and Harry C. Trimble of the Harvard Medical School had received honorary degrees from Harvard University. Anderson and Trimble received honorary doctor of science degrees from Cornell College.

Book Reviews

Man in the Primitive World. An introduction to anthropology. E. Adamson Hoebel. McGraw-Hill, New York, ed. 2, 1958. xvi + 678 pp. Illus. $9; text ed., $6.75.

The late Ralph Linton once remarked that an author who attempts to write an introductory book in anthropology faces the same dilemma as does a swimming instructor. He may throw the neophyte into a sea of small facts to sink or eventually swim. Or, he may choose to start with theory with the hope that the student will get bearings which will not be lost as he faces the reality of data. Linton concluded his analogy by saying that neither method had proved successful and that anthropology is a science which needs more than one introduction since it subsumes so many differing disciplines and traditions.

Hoebel's revised text will serve to reduce the pessimism which a number of anthropologists have shared with Linton. Using traditional chapter headings, the author manages to wed problem and subject matter in an unusually successful manner. Lucidly written, *Man in the Primitive World* does an excellent job of setting forth the central interest areas of anthropology. Eclectic in approach, the author manages not to become pallid and political in his choice of quoted positions and authorities.

Although they are hardly serious in the perspective of the full volume, I have certain reservations which are exemplified in chapters 32 and 33. Chapter 32, "Language and culture," in attempting to fill a gap so evident in many introductory texts, seems to overstress psycholinguistics and glottochronology. These are promising leads rather than tested analytic tools. And, while many linguists and anthropologists (including myself) share Hoebel's concern with these approaches, an introductory text possibly should include a more complete statement to the student concerning the status of their validation. Similarly, chapter 33, "Personality and culture," while clearly written, omits mention of a number of research techniques whose testing is part of the central focus of this aspect of the discipline. Yet, it is the author's right to decide whether to stress methodology or results in an introductory presentation. And he must make this decision or the book will soon become too large for the student's purse. At $6.75, the text edition is probably priced at the outside limit.

Well organized, clearly written, and beautifully printed and illustrated, *Man in the Primitive World* (a somewhat regrettable title) should find a place in the library of the general scholar as well as in the list of basic textbooks in anthropology. It clearly demonstrates that Hoebel's continuing contributions to the study of comparative law rest on a firm acquaintance with general anthropology.

RAY L. BIRDWHISTELL
Department of Anthropology, University of Buffalo

Nuclear Structure. Leonard Eisenbud and Eugene P. Wigner. Princeton University Press, Princeton, N.J., 1958. viii + 128 pp. $4.

Originally prepared as a section for the *Handbook of Physics* (McGraw-Hill), this small book provides a succinct description of the models and phenomena pertinent to an understanding of nuclear structure. The description is for the most part qualitative; however, quantitative formulae are often quoted. To write a short book on such a broad subject is difficult. To write a short *understandable* book is an even greater task. The authors have succeeded in selecting those comparisons and consequences of the various theories that contribute most to an understanding of the real significance of the numerous approaches to nuclear structure.

It is of course risky to write a book on the quickly changing field of nuclear physics, and the authors are quite naturally guilty of making the same mistakes that every physicist was making at the time of publication (for example, the choice of scalar-tensor-pseudoscalar for the beta-decay interaction). These mistakes do not, however, detract noticeably from the general value of the summary of nuclear structure. Topics covered include the energy systematics of complex nuclei, the properties of nuclear levels, nuclear reactions, the nucleon-nucleon interaction, α-decay, β-decay, and γ-decay. Emphasis is placed on the relations that these topics have to models of the nucleus.

Literature references are given at the end of the book, with brief comments relating to roles played by these investigations in the development of the subject. This manner of presentation is particularly pleasing and useful.

While the book can in no way be considered comprehensive, it is to be recommended as a fine brief survey of present attempts to understand the nucleus.

R. W. KING
Department of Physics, Purdue University

White Dwarfs. E. Schatzman. North-Holland, Amsterdam; Interscience, New York, 1958. vii + 180 pp. Illus.

The author has done brilliant work on the structure of, and the energy generation in, white dwarfs, and one may, therefore, expect considerable emphasis on theory rather than on observations in this monograph. Yet, it seems to me, this has resulted in a serious unbalance between the two. The discussion of the discovery of white dwarfs is quaint, to say the least. Thus, in the count for 1950, "discoverers" are named (rather incorrectly) for one-third of the total, but the name of the person who found the other two-thirds are omitted. Twenty-two white dwarfs are mentioned as components of binaries, though 33 had been published before the book was written.

One extensive table and two diagrams were reproduced from an article I published in 1952—with reference duly given, but I never was asked about this. Some of my discussions of, and conclusions from, these data are presented as if they were the author's own. Altogether, this hasty hash of the observational material takes up 13 pages, plus three pages of bibliography, while 160 pages are given over to theoretical considerations. Here the author is in his own field and has succeeded admirably in producing a logically developed and fascinatingly presented summary of our present knowledge—and speculation. The difference between the two is not sufficiently stressed, however, and often conclusions derived from pure theory are described as things *known*. Thus, the author laments the fact that the masses of only two white dwarfs are known (this is correct) but then states categorically that the range in mass *is* small and, still later, produces two separate diagrams in which

the masses of seven more white dwarfs are used, and described as *known*. I must admit to a feeling of unreality about theories "proved" in this manner.

The final chapter is frankly labeled "speculations," but the argument given to test the hypothesis that all bright stars evolve into white dwarfs is so oversimplified as to be no more than the proverbial straw man—put up to be knocked down.

Being primarily an observational astronomer, I feel that the main lesson to be drawn from so excellent a summary of our present theoretical knowledge is that observations of all kinds are urgently needed to put a firm foundation under the quicksand of astrophysical theories.

WILLEM J. LUYTEN
Department of Astronomy, University of Minnesota

The Planet Jupiter. Bertrand M. Peek. Macmillan, New York, 1958. 283 pp. Illus. $8.50.

Bertrand Peek has been for over 35 years an assiduous observer of the planet Jupiter and has served for 15 years as director of the Jupiter Section of the British Astronomical Association. In this book he summarizes the accumulated knowledge of the visual phenomena exhibited by the cloudy atmosphere of the planet, principally the motions and periods of rotation of the various belts and of the spots observed in them. In this respect this is an excellent "digest" of the wealth of material accumulated over half a century by an active group of British observers whose work is an outstanding example of the type of activity where amateur astronomers can make their best contribution. The professional astrophysicist may well feel somewhat disappointed by the rather sketchy nature of Peek's account of the more elaborate physical studies—spectroscopic, radiometric, radioelectric, and theoretical (and there is nothing at all on polarization)—but he cannot fail to learn a great deal about the basic superficial phenomena of the planet that he has seldom occasion to study for himself in any detail.

The British observers of Jupiter have been alarmed in recent years by a regrettable decrease in the number of amateurs actively engaged in the basic type of observation involving the timing of transits of spots across the central meridian of the planet. Peek's work is to some extent an appeal and a guide to younger amateurs to carry on the good work. He gives fairly complete instructions on how to observe most usefully the visual phenomena of Jupiter and how to reduce the data—a simple and straightforward process. The role of photographic observations is rather summarily dismissed (in five pages); this certainly does not do justice to the excellent and fairly continuous series of photographs secured over the past 50 years at the Lowell Observatory. Nor does Peek seem aware of the important physical investigations based on this photographic material of the general circulation of the Jovian atmosphere. He completely ignores the considerable visual, photographic, and polarimetric work of the French astronomers and the photometric studies of German and Russian astronomers. The brief section on the satellites and their phenomena gives next to nothing on their physical aspects. In this respect Peek's work definitely suffers from an excessively "insular" outlook.

Another serious deficiency is the almost total lack of bibliography, apart from the many references to the *Memoirs* of the British Astronomical Association, from which are extracted a good many drawings and sketches illustrating the main visual phenomena discussed in the text. There are also a number of Lowell, Pic-du-Midi, Mt. Wilson, and Palomar photographs, but little is said of the phenomena observed in blue, violet, and ultraviolet light.

Nevertheless, this is a useful and serious work by a serious amateur, and the book has obviously been prepared with the loving care of a dedicated observer; it gives a good and convenient summary of a tremendous amount of observational data, and the phenomena described—the complicated laws of motions of the spots—will long stand as a challenge to the theorist. This book fills a notable gap in the astronomical literature, and it will be consulted with profit by any astronomer, whether amateur or professional, who intends to take up Jovian studies, but it will have to be supplemented by reference to other sources.

G. DE VAUCOULEURS
Lowell Observatory, Flagstaff, Arizona

The Industrial Challenge of Nuclear Energy. Research uses, social problems. Papers given during the Second Information Conference on Nuclear Energy for Management, Amsterdam, 24–28 June 1957. Organisation for European Economic Co-operation, Paris, 1958. 301 pp. Illus. $3.50.

The Organisation for European Economic Co-operation includes the development of nuclear industries among its several spheres of international activity. Under the leadership of its newly created European Nuclear Energy Agency, cooperative programs are being planned in all major aspects of nonmilitary nuclear development, including such matters as the planning of nuclear test reactors, the construction of chemical processing facilities, and the international operation of demonstration power reactors. In addition, as an aid to industrial management generally, two conferences were held during 1957, the first in Paris in April and the second in Amsterdam during June. The papers which were presented over a period of several days at the latter conference comprise this volume.

A wide variety of material is covered, ranging from a general survey of nuclear energy in Europe, by L. Nicolaidis of Greece, to radioactive waste discharge problems, by M. d'Hont of Belgium. Authoritative descriptions of the ambitious British and French nuclear power programs are given, respectively, by G. C. Duckworth and Y. Teste. Other papers include discussions of nuclear research centers in Europe, reactor research, uranium supplies, and the manufacturing and processing of nuclear fuel elements.

Some of the material will, of course, become quickly out of date. For example, P. Huet, now director of the new European Nuclear Energy Agency, spoke of some of the plans of the OEEC to create this agency, now a reality. Cost estimates, such as those given for fuel costs for nuclear ship propulsion, are bound to change as the technology advances. But most of the material presented is of a fundamental character and will continue to be accurate, useful, and thought-provoking; moreover, it is described with a clarity which only experts can achieve. The book should therefore be in the library of those who are studying the general aspects of industrial nuclear development.

Furthermore, it is becoming obvious that the European requirements for expanding and cheaper sources of fuel for electric power will accelerate the development of a nuclear power industry. In addition to the well-publicized plans of the British, France alone is visualizing 8 million kilowatts of installed nuclear capacity by 1975. Italy, too, is moving rapidly with plans for at least three large atomic power plants, which are expected to be under construction within the next year. Europe will, therefore, become a major proving ground for the nuclear industry, and the United States will have much to learn. The lessons will be pertinent not only to our constructive participation in the European program but also to the development of our own nuclear industry.

Unfortunately, there is much of the story which is not covered in this book, partly because of the specific coverage which was planned and partly because the story is so large. Nevertheless, this

volume will occupy an important place on the library shelves of those in the United States who wish to familiarize themselves with the foundation which is currently being built to support a nuclear industry in Europe.

PHILIP N. POWERS
Internuclear Company, Clayton, Missouri

The Pattern of Asia. John E. Brush, Shannon McCune, Allen K. Philbrick, John R. Randall, Herold L. Wiens. Norton Ginsburg, Ed. Prentice-Hall, Englewood Cliffs, N.J., 1958. xiv + 929 pp. Illus. $11.65.

This is a long-awaited volume, welcome yet perhaps a little disappointing. Six specialists, with a combined background of many years in Asia, have cooperated in writing it. This gives the book authority, but the resulting style is heavy; so, too, is the volume itself.

A reviewer is under some handicap when the authors are personal friends, and especially when the book in question is in competition with one of his own. Equally, only those who have wrestled with the problem of evaluating so large and diverse a continent as Asia can appreciate the difficulties of generalization and the merit of the result.

The Pattern of Asia presents a broad picture of the major divisions of the "Asiatic Crescent," as the authors term the lands of "Asian Asia," from Turkey to Japan. Japan is discussed in 70 pages, while over 100 pages are devoted, respectively, to China, the Southeast, and the Southwest. South Asia—namely, India, Pakistan, Afghanistan, and Ceylon—is described in 256 pages. There is also a brief consideration of Central, or High, Asia, and there are two chapters on Soviet Asia.

This is not a volume to which one will turn for definitive statistics or penetrating interpretation; rather, it is sound regional description. For example, there is no critical evaluation of China's population, or of India's Five-Year Plan.

Most chapters close with a list of a dozen references, accompanied by helpful comments. Geographers should view with chagrin the small number of references to geographic literature per se. As a measure of the authors' previous work on Asia, it is interesting to note references to a combined total of 15 articles and one book by them, most of these by the senior author.

There are 161 photographs, many of them excellent but too often poorly reproduced, with an over-all grayness which loses important detail. Especially valuable are several aerial photographs of cities, with explanatory diagrams on facing pages. Captions are unusually long but should have been written in terms of the halftones rather than on the basis of the original photographs, for some distant landscape features referred to are scarcely visible.

The 38 maps are one of the poorest aspects of the book. If "a gentleman is known by the company he keeps," then a geographer may be judged by his maps. Many of the maps are cluttered and unclear; most lack artistry. In going through the book I early turned to the chapter on Pakistan. On page 632 I found a reference to map 26; curious about its coverage, I first thumbed through the next few pages and then counted back for 191 pages until I came to map 26. This proved to be the wrong reference; map 27, on pages 460–1, was apparently meant. This is exasperating, as is the attempt to locate the 20 tables or five plates. The composite climatic graphs seem unsuccessful. More than the usual number of typographical errors are present.

The treatment of India is perhaps the most successful, doubtless due to the long residence there of Professor Brush; in the treatment of some other areas there is an inadequate feel for the people or landscape. Students of Arab lands will be interested to find that discussions of Israel (7 pages) and Lebanon (3 pages) are combined in the same chapter.

The preface states that the theme of the volume is "a more basic understanding of the processes of change which are so radically transforming the Asian landscape," but one might read through the book without being aware of such a motif. Communism, technical assistance, land reform, and economic planning receive but passing mention. The preface goes on to remark that the treatments of the several authors have led to considerable diversity in emphasis, a problem which the senior author has resolved well.

This is a splendid contribution to our understanding of Asia, but one wonders whether the authors would "do it again" this way if they had not signed contracts years ago.

GEORGE B. CRESSEY
Department of Geography, Syracuse University

The World of the Electron Microscope. Ralph W. G. Wyckoff. Yale University Press, New Haven, Conn., 1958. xiii + 164 pp. Illus. + plates. $4.

This is not a book written for the specialist in electron microscopy, but rather an exposition for both scientist and layman of the development of a very rapidly expanding instrumental specialty. As Wyckoff points out, electron microscopy is not unique in its pattern of development, and it provides a convenient example for illustrating certain characteristics of the growth of instrumental specialties. Thus, progress in electron microscopy has often been dependent on what may seem to be trivial improvements in specimen preparation. The growth of electron microscopy in the field of cell structure, following on the development of suitable techniques of fixation, embedding, and microtomy, is an impressive example of this kind of sequential development.

The book is well written and makes enjoyable reading. It is illustrated with 16 plates of high-quality electron micrographs and has a relatively brief but adequate index. Wyckoff adopts a philosophical note in the concluding chapter, and one must sympathize with many of his views, particularly with his appeal for more basic research in this country.

ALAN J. HODGE
Department of Biology, Massachusetts Institute of Technology

Social Class and Mental Illness. A community study. August B. Hollingshead and Frederick C. Redlich. Wiley, New York; Chapman & Hall, London, 1958. xii + 442 pp. $7.50.

Every research monograph has its inevitable quota of limitations and imperfections, and this volume is certainly no exception. What makes the present book exceptional is the new ground it sowed and the reapings it now contributes, both to the healing professions and to the behavioral sciences.

A sociologist and a psychiatrist here collaborate to examine two sets of seemingly discrete phenomena: (i) mental illness and (ii) the socio-economic class system of the urban American community. Their purpose is to determine the effects of the social class system on the availability and character of the psychiatric treatment of patients. From intensive investigations in New Haven, Connecticut, of a large patient population and its therapeutic facilities, Hollingshead and Redlich demonstrate for the first time that who comes for and secures treatment, how he is referred, where he is treated, what kind of therapy is administered, what the frequency and duration of the treatment program and the costs and charges for a given time unit of treatment are, all hinge to a significant and unexpected degree on who, in terms of class position, the patient happens to be.

At the very least, the authors give us a fully documented case study of the American social class system in action,

within the framework of a healing profession.

In their concluding chapters the authors go beyond the confines of a case study to follow the implications of their findings wherever they lead, even though these lead, as they are aware, into controversy. It is here that data, insight, and the large social view produce a serendipitous yield of "tentative inferences" that must be taken into account as future guidelines both for research and for social policy.

The latter inferences range from public education in mental health matters, to evaluation of present methods of treatment and development of new methods, to professional training of therapists.

One can perhaps convey the significance and impact of this book in capsule form by suggesting that it stands in the tradition of Myrdal's classic work, *An American Dilemma*. Despite controversy, psychiatry and the community at large, well and sick, will stand in the authors' permanent debt.

LEO SROLE

Cornell University Medical College, New York

Snakes in Fact and Fiction. James A. Oliver. Macmillan, New York, 1958. xiii + 199 pp. Plates. $4.95.

James Oliver wrote this book to answer "a majority of the questions most frequently asked about snakes," and this he has done in language free from technicalities. Although a great many subjects are dealt with briefly, emphasis is placed on a few old favorites such as giant snakes (two chapters), aggressive and dangerous snakes and their rating, and snake charmers and worshippers.

The account of the famous snake dance of the Hopi Indians of Arizona includes a good discussion of how the Hopis handle rattlesnakes with relative safety. Of special interest is impressive evidence that the anaconda grows to be at least 37 feet long. Here Oliver deals with a highly controversial subject, and his conclusion will raise the hackles of many a herpetologist. Incidentally, he transfers to the New World the honor of having the largest of all snakes, but he gives the Old World credit for the most deadly one.

In spite of the fact that snakes universally arouse strong and varied emotions, there are, in English, almost no accurate, readable, up-to-date books about them. I exclude certain excellent special-purpose works such as regional guides; these are not intended to be read straight through. It is, therefore, a pleasure to recommend a book not only designed to be read like a story but written well enough to compete with good stories. The author is curator of reptiles of the New York Zoological Society and carries on with notable success the tradition started at the zoological park in the Bronx by the late Raymond L. Ditmars, renowned reptile specialist and educator.

Technical names are omitted from the text but entered in the ample index, after the common names. Lack of a bibliography is in part offset by the inclusion of names of herpetologists and other workers along with the accounts of their contributions. The 20 halftone pictures are produced on 12 plates and include two photographs of the Hopi snake dance.

CLIFFORD POPE

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New Books

Principles of Biological Microtechnique. A study of fixation and dyeing. John R. Baker. Methuen, London; Wiley, New York, 1958. 372 pp. $7.50.

Abbreviations Dictionary. Abbreviations, contractions, signs and symbols defined. Including the Greek alphabet, international civil aircraft markings, numbered abbreviations, proofreader's marks, punctuation and diacritical marks, radio alphabet, Roman numerals, ship's bell time signals, signs and symbols. Ralph De Sola. Duell, Sloan and Pearce, New York, 1958. 186 pp. $4.

Baillière's Atlas of Male Anatomy. Revised by Katharine F. Armstrong. Baillière, Tindall & Cox, London, ed. 4, 1958 (order from Williams & Wilkins, Baltimore). 34 pp. $3.25.

Behind the Sputniks. A survey of Soviet space science. F. J. Krieger. Public Affairs Press, Washington, D.C., 1958. 386 pp. $6.

Bibliography of Food. A select international bibliography of nutrition, food and beverage technology and distribution, 1936–56. E. Alan Baker and D. J. Foskett. Academic Press, New York; Butterworths, London, 1958. 343 pp.

Bibliography on the Genetics of Drosophila. pt. 3. Irwin H. Herskowitz, Indiana Univ. Press, Bloomington, 1958. 296 pp. Paper.

Cholesterol. Chemistry, biochemistry, and pathology. Robert P. Cook, Ed. Academic Press, New York, 1958. 554 pp. $15.

Coastal Sand Dunes of Oregon and Washington. Memoir 72. William S. Cooper. Geological Soc. of America, New York, 1958. 169 pp.

Comprehensive Inorganic Chemistry. vol. 7, *The Elements and Compounds of Group IVA.* M. Cannon Sneed and Robert C. Brasted. Van Nostrand, Princeton, N.J., 1958. 311 pp. $7.50.

Current Trends in Heterocyclic Chemistry. Proceedings of a symposium held at the John Curtin School of Medical Research, Australian National University, Canberra, 2–4 September 1957, under the auspices of the Chemical Society. A. Albert, G. M. Badger, C. W. Shoppee, Eds. Academic Press, New York; Butterworths, London, 1958. 179 pp. $5.50.

Danger in the Air. Oliver Stewart. Philosophical Library, New York, 1958. 213 pp. $6.

D'Arcy Wentworth Thompson. The scholar-naturalist, 1860–1958. Ruth D'Arcy Thompson. Oxford Univ. Press, New York, 1958. 255 pp. $4.

Dispersion of Materials. Rolt Hammond. Philosophical Library, New York, 1958. 239 pp. $10.

Electromagnetic Isotope Separators and Applications of Electromagnetically Enriched Isotopes. R. H. V. M. Dawton, M. L. Smith, W. Walcher. J. Koch, Ed. North-Holland, Amsterdam; Interscience, New York, 1958. 322 pp. $7.50.

Elementary Number Theory. Edmund Landau. Translated by Jacob E. Goodman. Chelsea, New York, 1958. 256 pp. $4.95.

Essays on Individuality. Felix Moreley, Ed. Univ. of Pennsylvania Press, Philadelphia, 1958. 270 pp. $5.

Estimation of Thermodynamic Properties of Organic Compounds. George J. Janz. Academic Press, New York, 1958. 220 pp. $6.

Fibre Microscopy. Its technique and application. J. L. Stoves. Van Nostrand, Princeton, N.J., 1958. 291 pp. $7.50.

General Cytochemical Methods. vol. 1. J. F. Danielli, Ed. Academic Press, New York, 1958. 482 pp. $12.80.

Miscellaneous Publications

(Inquiries concerning these publications should be addressed, not to Science, *but to the publisher or agency sponsoring the publication.)*

Guideposts for the Gifted Children Themselves. Guideposts for Administrators. Guideposts for Teachers of Gifted Children. Guideposts for Parents of Gifted Children. Ruth Strang. Bureau of Publications, Teachers College, Columbia Univ., New York, 1958. 4 folders, $0.60 per set.

Petroleum Sourcebook, 1958. A regional bibliography of petroleum information. Curtis Stevens, Ed. National Petroleum Bibliography, Box 3586, Amarillo, Tex., 1958. 179 pp. $6.

List of Scientific Papers, Second United Nations International Conference on the Peaceful Uses of Atomic Energy. Chronicle of the United Nations, Document Service, Nos. 5–7. Chronicle of the United Nations, 234 West 26 St., New York 1, 1958. 24 pp. Free.

Energy in Latin America. Study prepared by the Secretariat of the Economic Commission for Latin America. Department of Economic and Social Affairs, United Nations, Geneva, 1957 (order from Columbia Univ. Press, New York). 268 pp. $2.50.

Fundamentos del proyecto de creación del Observatorio Astronomico de la Facultad de Humanidades y Ciencias, Publ. No. 1, 14 pp.; *El Proyectado Observatorio Astronomico Interamericano.* Publ. No. 3, Felix Cernuschi, 20 pp. Departamento de Astronomia, Facultad de Humanidades y Ciencias, Universidad de la República, Montevideo, Uruguay, 1958.

Reports

Isolation of Colorado Tick Fever Virus from Rodents in Colorado

Although Colorado tick fever virus has been isolated frequently from man and from the Rocky Mountain wood tick, *Dermacentor andersoni* Stiles (*1*), spontaneous infection of wild mammals has not been previously reported. Species expected to harbor the virus must necessarily be hosts of the immature stages of *D. andersoni,* the only tick that has been incriminated in transmission of the disease to man. We have obtained serologic evidence suggesting the occurrence of natural infections in one such animal species, the Columbian ground squirrel, *Citellus columbianus,* in western Montana and have found this species to be readily susceptible to experimental infection. This report records the first isolations of virus from mammals in nature. The hosts were the golden-mantled ground squirrel, *Citellus lateralis lateralis,* and the porcupine, *Erethizon dorsatum epixanthum,* collected in western Colorado.

Several members of a religious order residing on and operating a large ranch near Snowmass, Pitkin County, Colo., contracted Colorado tick fever in 1956 and 1957. Studies made 10–13 August 1957 revealed that golden-mantled ground squirrels occurred abundantly in pastures adjacent to the residence building and along roadsides on and near the ranch. Twenty were shot and four were captured alive. Two porcupines were captured about 2 miles from the residence. Other animals collected were one chipmunk, *Eutamias* sp., one deer mouse, *Peromyscus* sp., and one woodchuck, *Marmota flaviventris.* Blood samples were taken and refrigerated for transport to the laboratory. Fifteen adult *Dermacentor andersoni* were found on the porcupines, and 97 immature *D. andersoni* and 30 immature *Ixodes sculptus* on the squirrels. These and 33 adult *D. andersoni* collected from vegetation were saved for testing.

Blood samples were tested for presence of virus by triturating the clot in about 2 ml of physiologic saline solution, centrifuging the suspension at moderate speed, and injecting 0.05 ml of the supernatant intraperitoneally into each of a litter of six 4-day-old white mice. Transfers to passage mice were made by inoculation of brain suspensions.

Death resulted in four of six primary test mice injected with blood from one squirrel and in all passage mice. One mouse died in each litter injected with blood from another squirrel and from porcupine 34459, and several mice died in the passage litters. All three isolates were identified by neutralization tests as Colorado tick fever virus.

Blood samples collected 21 August from the four living ground squirrels were tested for virus and for neutralizing antibodies. No neutralizing antibodies were found, but virus was isolated from the blood of two of the animals, one of which had also been positive when it was bled in the field 7 days earlier. These four squirrels were then infested with virus-free laboratory-reared nymphs of *D. andersoni* to determine whether the blood of any of these animals contained sufficient virus to infect engorging ticks. One squirrel died before the ticks had opportunity to feed, but engorged ticks were obtained from the three remaining animals. When tested as adults, the ticks from one squirrel from which virus had been isolated earlier proved to be infected.

Serum samples from 20 ground squirrels, the deer mouse, the chipmunk, and porcupine 34459 did not contain neutralizing antibodies, but the sample from ground squirrel 34444, the woodchuck, and porcupine 34460 neutralized 264, 40, and 576 LD_{50} of Colorado tick fever virus, respectively.

The ticks obtained in the field were tested in separate lots according to host, species, and stage of tick—that is, larvae and nymphs from the same animal were tested separately. Ticks were triturated with sterile sand in physiologic saline solution containing 10 percent rabbit serum, streptomycin, and penicillin. Each sample was injected intraperitoneally into a litter of six 4-day-old mice. On the 8th day after inoculation, unless sickness was noted earlier, two mice of each litter were sacrificed and a brain suspension was passed to another litter. No infection was demonstrated in the adult ticks. By passage, virus was isolated from immature *D. andersoni* from two ground squirrels. One lot consisted of three larvae and the other of four nymphs. The host of the nymphs was one of the squirrels from which virus was isolated (*2*).

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GLEN M. KOHLS
WILLIAM L. JELLISON
Rocky Mountain Laboratory, National Institute of Allergy and Infectious Diseases, Hamilton, Montana

References and Notes

1. C. M. Eklund, G. M. Kohls, J. M. Brennan, *J. Am. Med. Assoc.* 157, 335 (1955).
2. We are indebted to Dr. Gordon Meiklejohn, of the University of Colorado Medical School, for informing us of the occurrence of the Colorado tick fever cases at Snowmass and to Rev. M. Leo Slatterie for permission to collect animals and ticks on the monastery grounds.

28 March 1958

Taxonomic Implication of Actinophage Host-Range

Bacteriophages are known which attack hosts of different species and genera (*1*). However, bacterial viruses attack only closely related hosts. Therefore susceptibility to particular bacteriophages is used to speciate certain bacteria (*2*). Members of the genera *Nocardia* and *Streptomyces* are sensitive to their respective bacteriophages (*3*). Recently we found that two of 12 actinophages, initially isolated on streptomycetes, were able to attack some species of *Nocardia.* We therefore undertook to isolate additional streptomyces phages and nocardia phages in order to determine whether or not other intergeneric susceptibilities existed (*4*).

The strains of *Streptomyces* employed in this investigation have been previously described (*5*). The strains of *Nocardia* used, except for *Nocardia* sp. strain 3403, were supplied by Norman F. Conant, of Duke University. *Nocardia* sp. strain 3403 was obtained from the collection of the New Jersey Agricultural Experiment Station. The cultures of *Actinoplanes* and *Streptosporangium* were supplied by John Couch, of the University of North Carolina. The strains of *Micro-*

All technical papers are published in this section. Manuscripts should be typed double-spaced and be submitted in duplicate. In length, they should be limited to the equivalent of 1200 words; this includes the space occupied by illustrative or tabular material, references and notes, and the author(s)' name(s) and affiliation(s). Illustrative material should be limited to one table *or* one figure. All explanatory notes, including acknowledgments and authorization for publication, and literature references are to be numbered consecutively, keyed into the text proper, and placed at the end of the article under the heading "References and Notes." For fuller details see "Suggestions to Contributors" in *Science* 125, 16 (4 Jan. 1957).

Table 1. Host ranges of streptomyces-phages and nocardia-phages with respect to several genera of the Order Actinomycetales. SP- and NP- denote phages initially isolated on streptomycetes and nocardia respectively. Lysis of a host by a standard phage suspension is indicated by a plus sign; no lysis is denoted by a minus sign.

Hosts	Actinophages					
	SP-3	SP-4	SP-8	NP-3	NP-4	NP-5
Streptomyces griseus S34	−	+	−	+	−	−
Streptomyces griseus S104	+	+	+	+	+	+
Streptomyces griseus 1945	−	−	+	+	+	−
Streptomyces olivaceus S11	+	+	+	+	+	−
Streptomyces venezuelae S13	+	+	+	+	+	+
Streptomyces cyaneus S45	−	−	−	+	−	−
Nocardia sp. 3403	−	−	−	−	−	+
Nocardia paraguayensis	+	+	+	+	−	−
Nocardia madurae	−	−	−	−	+	−
Nocardia brasiliensis	−	−	−	−	−	−
Nocardia asteroides	−	−	−	−	−	−
Actinoplanes sp.	−	−	−	−	−	−
Streptosporangium sp.	−	−	−	−	−	−
Mycobacterium phlei	−	−	−	−	−	−
Micromonospora sp.	−	−	−	−	−	−

monospora and *Mycobacterium* were from the culture collection maintained at the University of Minnesota. The general precedures for isolating and purifying actinophages followed those previously published (*6*). The nutritive substrate used in earlier work did not support rapid growth of all the organisms studied here. Therefore a modified medium was devised, containing the following ingredients: Difco peptone, 5 g; Difco yeast extract, 3 g; glucose, 1 g; Difco casamino acids, 1 g; Armour beef extract, 2 g; Difco agar, 15 g; deionized water, 1 liter.

Eleven soil samples, collected in Minnesota, have yielded three streptomyces phages and five nocardia phages. Of the three newly isolated streptomyces phages, one attacked *Nocardia paraguayensis* as well as several members of the genus *Streptomyces* (Table 1). Of the five newly isolated nocardia phages, three attacked streptomycetes. The strains of *Actinoplanes, Streptosporangium, Micromonospora,* and *Mycobacterium* used in this investigation were resistant to all streptomyces phages and nocardia phages tested.

At the present time, the genera *Actinomyces* and *Nocardia* are taxonomically placed in the family Actinomycetaceae, whereas *Micromonospora* and *Streptomyces* are placed in the family Streptomycetaceae. In view of the results reported here, it seems that the genera *Nocardia* and *Streptomyces* are closely related and should not be separated into different families. This interpretation is supported by the recent discovery that *Nocardia asteroides* produces conidiospore-like structures (*7*). The formation of chains of conidiospores is one of the fundamental criteria for differentiating *Nocardia* and *Streptomyces*. In fact, it has been recently pointed out that there is no clear-cut distinction between the genera *Nocardia* and *Streptomyces* and that the separation of *Streptomyces* from *Nocardia* is invalid (*8*).

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4. This investigation was supported in part by research grants from the National Institute of Allergy and Infectious Diseases, Public Health Service, and from the Medical Research Fund of the University of Minnesota. We are indebted to Dr. Norman F. Conant of Duke University for the strains of *Nocardia* used, except strain 3403, and to Dr. John Couch of the University of North Carolina for the cultures of *Actinoplanes* and *Streptosporangium*.
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21 March 1958

Detection of Ultraviolet Absorbing Spots on Paper Chromatograms by Blueprint Paper

Many organic compounds having strong ultraviolet absorption at 250 to 260 mμ can be detected on paper chromatograms by the photographic method of Markham and Smith (*1*) or Haines and Drake (*2*). The chromatogram is used as a "negative" over a sheet of contact printing paper. The light source is a quartz mercury arc, used with a filter that transmits primarily the intense 253.7-mμ line. Substances having high extinction at this wavelength show as white spots on a black background when the print is developed. Several refinements of this technique have been proposed (*3, 4*), but it requires a darkroom and the usual developing and fixing baths which are not conveniently available in many laboratories.

This report (*5*) describes the use of ferric ferricyanide blueprint paper, which is relatively insensitive to visible light and can be handled without special precautions in any well-lighted laboratory (though direct sunlight must be avoided). It can be developed in a few seconds by rinsing with cold tap water. Excellent "prints" are obtained even with an inexpensive unfiltered mercury arc light. The cost of blueprint paper is less than one-fifth that of photographic printing paper.

Blueprint paper is available from several manufacturers and in various grades. All will probably give satisfactory results, although there will be minor differences in speed, depth of color, and contrast. In this work, Dietzgen XL, a thinly-coated paper, has been used. It seems to give somewhat greater exposure latitude, lighter blue background, and better-defined spots than some other papers.

Two kinds of low-wattage ultraviolet lamps are useful. One is a quartz "germicidal" mercury arc emitting over 90 percent of its energy at 254 mμ. The other is a "black light" fluorescent lamp, whose phosphor emits most of its energy in the long-wave ultraviolet near 360 mμ. Both lamps also emit visible light, but filtering is unnecessary because of the low sensitivity of blueprint paper to wavelengths above 400 mμ. The lamps are mounted on a frame about 2 inches above the paper. For one-dimensional chromatograms up to 2 inches wide and 12 inches long, one lamp is sufficient; for wider chromatograms several parallel lamps must be used (or a single high-wattage lamp set 12 inches or higher above the paper). Complete equipment and materials needed for ultraviolet blueprinting of chromatograms are obtainable from Microchemical Specialties Company, Berkeley, Calif.

The technique has been used so far primarily with test strips and one-dimensional chromatograms of Whatman No. 4 paper (available in 600-foot rolls and widths of ½, 1, 1½, . . . inches). Blueprint paper is taken from a 2-inch wide roll in a dispenser and laid on a thin, flexible-plastic, 12-inch rule. The filter paper strip is laid on the sensitized surface of the blueprint paper, and paper clips are used to attach the ends of the papers to the plastic rule. If better contact is desired, more clips may be used at intervals of 2 inches; the clips show

on the print, but this does not interfere with detection of spots. For two-dimensional chromatograms, a printing frame is desirable (*4*). Poor contact gives less well-defined spots and slightly less sensitive detection.

Exposure time is much longer than for photocopy paper and is not very critical, but a photographic printing timer is useful. Correct exposure should be determined for the particular lamp, filter paper, and blueprint paper used. With Whatman No. 4 paper, at 254 mμ, a 1-minute exposure gives a very pale blue background, and spots are detected with maximum sensitivity. A 3-minute exposure gives a darker background, against which spots show with maximum contrast and definition but with slightly less sensitivity. Longer exposures simply lower the sensitivity of detection and are useful only if it is desired that weak spots not show on the print. At 360 mμ, exposure time is about half that at 254 mμ. With thick papers a 10-minute exposure may be necessary, unless a solution of 25 percent heavy white mineral oil in isooctane is sprayed or poured on the paper. The increased transparency reduces exposure time by a factor of 2 to 3, and improves the definition of spots. It lowers sensitivity of detection, however, by a factor of 2 to 3, because the intensification ("hyperchromic absorption") of spots on dry filter paper is lost (*6*).

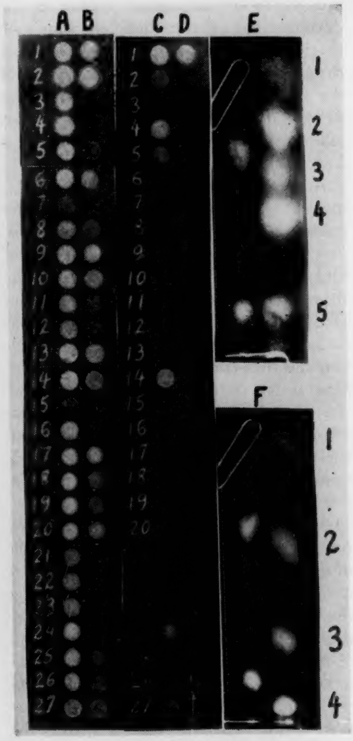

Fig. 1. Blueprints of ultraviolet spots on Whatman No. 4 filter paper. Columns A to D are 2-μl test spots. Solutions in columns A and C are 0.05*M* (0.1 μmole), in columns B and D, 0.005*M*. (0.01 μmole). A and B blueprinted at 254 mμ, 1 minute, C and D at 360 mμ, 1 minute. Identification: 1, pyrene; 2, phenanthrene; 3 acenaphthene; 4, acenaphthylene; 5, ergosterol; 6, testosterone; 7, estradiol; 8, DDT; 9, DDE; 10, sulphenone; 11, sevin; 12, kelthane; 13, mitox; 14, rotenone; 15, 2,4-D; 16, methadone; 17, adenosine; 18, nicotinamide; 19, pyridoxine; 20, ascorbic acid; 21, tryptophan; 22, maleic acid; 23, fumaric acid; 24, potassium ferricyanide; 25, sodium molybdate; 26, copper acetate; 27, ferric chloride. Columns E and F are chromatograms, with β-methoxypropionitrile as the stationary phase and isooctane as the mobile phase, blueprinted at 254 mμ, 3 minutes. The spots on the left are azo dyes used as reference standards. Spots on right are: Chromatogram E (all 0.08 μmole): 1, fluorene; 2, methyl cholanthrene; 3, 7,8-benzoquinoline; 4, 3,4-benzoquinoline; 5, acenaphthenol. Chromatogram F (all 0.1 μmole): 1, diazinon; 2, trithion; 3, parathion; 4, guthion.

After exposure, the blueprint paper is washed in cold water under the tap for 5 to 10 seconds. The paper is then pressed flat on a ferrotype plate or other smooth flat surface and allowed to dry for a few minutes. To prevent curling the paper must be removed before it is completely dried and pressed flat between sheets of blotter paper for 10 minutes or more. Starting lines, solvent front lines, and other notations in ink or pencil on the chromatogram are blueprinted like the ultraviolet spots, so that R_f can be measured directly on the print.

If a chromatogram or spot test is to be blueprinted both at 254 and at 360 mμ, the test at 360 mμ must be done first, because the exposure at 254 mμ may cause chemical changes in the absorbing substance that cause the spot to absorb at 360 mμ or even to develop a visible color. Pyridine derivatives, such as nicotinamide, for example, are not detected by blueprinting at 360 mμ, but the decomposition products formed during blueprinting at 254 mμ cause the spot to turn yellow and to absorb strongly at 360 mμ.

Ultraviolet-sensitive papers other than ferric ferricyanide blueprint paper have been tried and found to be less satisfactory. Diazotype papers give dark spots on a white background, but neither the sensitivity nor the contrast is as good as that of blueprint paper. Ferric-silver "Vandyke" papers (such as Dietzgen No. 227) give white spots on a dark brown background but are more expensive and not significantly better than blueprint paper.

By using an intense high-pressure mercury arc and a nickel sulfate–cobalt sulfate solution in a Lucite cell as a filter, Bernasconi *et al.* (*7*) obtained a narrow ultraviolet band (300 to 350 mμ) useful for selective photographic detection of compounds with maxima in this region. The filter system, however, would probably transmit too little light to be suitable for the relatively insensitive blueprinting method, although it is satisfactory with silver halide papers.

Sample blueprints of spot test strips and of chromatograms are shown in Fig. 1. If the molecular extinction coefficient of a substance at 254 mμ is of the order of 10,000, a spot of 0.001*M* solution can be detected. Absorption at 254 mμ has been used for detecting purines and pyrimidines (*1*) and ketosteroids such as cortisone (*3, 8*). Figure 1 shows that blueprint paper is also useful for detecting certain sterols, insecticides, acaricides, many aromatic compounds, and some inorganic ions. Absorption at 360 mμ is of more limited use but can be used to detect polynuclear aromatics and other compounds with long sequences of conjugated double bonds, some aromatic nitro compounds, and a few inorganic ions.

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24 March 1958

Determination of Deuterium Oxide in Water by Measurement of Freezing Point

A simple, rapid method for determination of deuterium oxide (D_2O) in water has been devised. The most widely used and precise methods involve use of the mass spectrometer and the falling drop. Other less common techniques include measurements of density gradient, phase-contrast refraction, sinking rate of a quartz float, infrared absorption, and thermal conductivity. No reference has been found to a method based on elevation of the freezing point of water.

The freezing point of deuterium oxide

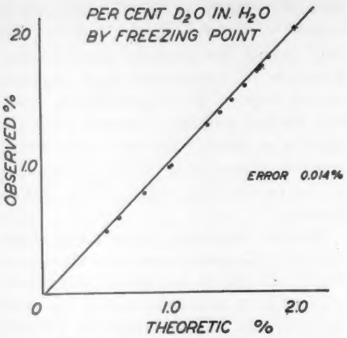

Fig. 1. Observed concentrations, expressed as percentage of D_2O in water, plotted against the theoretic values. The error (± 0.014) is expressed as deviation from the theoretic straight line shown.

Table 1. Evaluation of accuracy of the method.

No. of determinations	Standard error (%) D_2O	D_2O concn. range (%)	Type of measurement
14	± 0.014	0–2	Blind
210	± 0.019	0–5	Repetitive

is 3.802°C. Hence, a method for measuring freezing points to a thousandth of a degree should permit differentiation of at least 0.01 percent deuterium oxide in water. Such a method is now available in the form of the Fiske osmometer (*1*). The operation of this instrument is based on the principle that slightly supercooled solutions can be rapidly frozen by agitation and that the temperature of the ice crystals can be measured during the several seconds it remains constant. This temperature is considered to be the freezing point. The apparatus is designed to operate at temperatures below zero, but proper adjustments of the calibration will allow measurements a degree or so above zero. The temperature is measured by means of a thermistor in a bridge circuit. If measurements are confined to a narrow temperature range (a degree or so), potentiometer readings are essentially linear.

When the instrument is used as an osmometer, the thermistor is calibrated by determining the potentiometer readings at which 100 and 500 milliosmolar solutions of sodium chloride freeze. When these are adjusted to provide dial readings of 100 and 500 on the potentiometer, the osmolarity can be read directly.

Since the freezing point of 100 milliosmols of sodium chloride in distilled water is -0.1858°C and that of distilled water is 0°C, these liquids were used for the purpose of calibrating the osmometer. One hundred scalar divisions extended over a temperature range of 0° to 0.2044°C for 0 to 5 percent solutions of D_2O in distilled water. For assessment of linearity, 0.5, 1, 2, 3, 4, 10, 15, 20, and 25 percent solutions of D_2O in distilled water were studied. Calibration was checked by determining concurrently the 100 milliosmolar solution of sodium chloride and the water with each series of measurements of the freezing points. Thirty separate determinations were made of each dilution.

It was apparent that the precision of the method was limited by the sensitivity of the osmometer, which, incidentally, can be increased. Repeated determinations were reproducible to 0.2 scalar division of the potentiometer. Linearity within the range of 0 to 5 percent D_2O was also within less than 0.2 scalar division. Figure 1 and Table 1 show the sensitivity and accuracy of the method. For a concentration range of 0 to 2 percent D_2O in water, the D_2O was determined to a concentration of 0.05 percent.

The simplicity and reliability of this method ensure its usefulness in the study of many problems involving D_2O in the medical, biologic, physical, and chemical fields, provided that levels of concentration of D_2O are such as to fall within the range of the osmometer. The sensitivity of the method can be increased by more precise determinations of the freezing points (*2*).

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Notes

1. Fiske Associates, Boston, Mass.
2. This work was aided by grants from the U.S. Public Health Service (H143), the Upjohn Company, Kalamazoo, Mich., and the Thibodeaux Foundation.

21 March 1958

Accumulator Plants and Rock Weathering

Accumulator plants may be defined as those that take up certain specific elements to a much greater degree than most plants. Accumulators that selectively take up elements harmful to agriculture—such as selenium and molybdenum—have been extensively studied, but little has been written about the problems posed by plant accumulators of major constituents of the earth's crust such as silica, aluminum, and iron. Although it is generally recognized that biochemical factors are important agents in surficial processes, the possibility that accumulator plants may withdraw from the earth geologically significant amounts of various elements has not previously been pointed out so far as I am aware. The amount of silica taken out of the ground by certain plants is sufficiently large to warrant consideration of this process as an important factor in the development of silica-deficient soils such as the laterites. Horsetail or "scouring-rush," some dicotyledons, and many of the monocotyledons such as corn, palm trees, bamboo, reeds, and other grasses take up large amounts of silica (see Table 1).

According to Amos and Dadswell (*1*), more than 375 species of tropical timber trees must be classed as silicic—that is, they contain more than 0.05 percent SiO_2 (dry weight). Many species of the tropical hardwoods studied by Amos and Dadswell range between 2 and 3 percent SiO_2 (dry weight); some species of bamboo and rush contain 3 times this amount. One order of trees common in Brazil, the Chrysobalanea, especially the genus *Moquilea,* is unusually rich in silica, and the heavy bark of trees of this genus contains slightly more than 50 percent SiO_2 (dry weight) (*2*).

According to Bear (*3*), tropical forests produce from 10 to 20 tons dry weight of new growth per acre above ground each year. If we assume that a forest in the tropics containing good silica accumulators averages 3 percent dry weight of silica and produces approximately 13 tons dry weight of new growth per acre per annum, it is readily calculated that such a forest would abstract from the soil about 0.4 ton of silica per acre per year. This is equivalent to 1 ton of silica per acre each 2½ years.

A basaltic lava having a density of about 3 and containing 49 percent SiO_2 would have about 2000 tons of silica per acre foot. It is apparent, then, that a tropical jungle of silica-accumulator vegetation could in 5000 years easily remove silica equivalent to that in 1 acre foot of basalt. The bulk density of the lateritic soils commonly ranges from 30 to 40 percent of the bulk density of the parent basalt. If we assume that 3 to 1 is a fair approximation of the ratio of parent rock to residual lateritic soil, volume for volume the laterite and parent basalt would be nearly equivalent, but the lateritic soil would represent only about one-third the weight of the fresh parent rock. If this lateritic soil contained about 35 weight percent SiO_2 (see Hough and Byers, *4*) there would be approximately 475 tons of silica per acre foot residual from the 2000 tons of silica in 1 acre foot of fresh basalt. The hypothetical tropical jungle of silica-ac-

Table 1. Analyses of some silica- and iron-accumulator plants (arranged in order of decreasing silica content, dry weight).

SiO_2 (% dry wt.)	Ash (% of dry wt.)	Weight percent in ash*									
		SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	P_2O_5	SO_3	Cl
Giant reed, *Arundu donax* (leaves)†											
9.5	12.5	76.9	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Common gromwell, *Lithospermum officinale*‡											
8.11	29.30	27.68	n.d.	0.28	3.15	59.01	0.77	6.17	2.17	0.77	n.d.
Water chestnut, *Trapa natans*§											
5.53	19.62	28.00	n.d.	26.51	6.36	16.28	2.06	6.47	n.d.	2.63	0.55
Giant horsetail, *Equisetum telmateja* (Ehrh)‖											
5.40	17.39	31.08	0.96	23.39	2.20	13.50	1.41	9.26	1.26	8.95	6.12
Giant reed, *Arundu donax* (stems)†											
3.9	5.5	70.8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
English rye grass, *Lolium perenne* L.#											
3.46	12.12	28.51	n.d.	1.04	2.34	10.15	1.26	37.80	9.64	5.78	5.57
Bluegrass, *Poa maritima*‡											
3.23	6.81	47.48	n.d.	4.58	2.99	4.28	10.05	11.37	4.42	1.75	11.09
China laurel, *Antidesma pulvinatum* (Hil.)**											
2.97	4.26	69.72	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Palm, *Calamus rotang*‡											
2.15	3.16	67.96	n.d.	0.33	11.81	16.97	0.56	0.65	0.29	0.76	n.d.
Field horsetail, *Equisetum arvense* (L.)											
0.37	6.05	6.19	n.d.	37.35	6.90	19.80	7.72	4.26	2.87	6.78	5.49

* n.d., not determined. † Collector and analyst, C. G. Engel, U.S. Geological Survey, Pasadena, Calif., Feb. 1958. ‡ E. T. von Wolff, single analysis (*7*, pp. 110, 111, 121). § E. T. von Wolff, av. of two analyses (*7*, p. 133). ‖ G. Mariani, individual analysis (*8*). # E. T. von Wolff, av. of 11 analyses (*7*, p. 121). ** L. E. Wise, wood samples from Hawaii (*9*).

cumulator vegetation would require 2.5 × (2000–475) years or about 3800 years to convert 1 acre foot of fresh basalt to 1 acre foot of this lateritic soil if silica were removed solely through the agency of these plant accumulators.

Not all the silica moving into plant accumulators would be lost. Nevertheless, whether the silica is present in the plant as opal, as fine-grained quartz, as inorganic compounds, or as organic compounds, it would be highly vulnerable to chemical and physical erosion while the plant matter was decomposing. In areas of high rainfall where a tropical downpour equivalent to several inches of precipitation may take place in a few hours, much of the organic debris could be washed into the nearest drainage channel. The reality of such a process is evident in the high organic content of the brown and black waters so common in the tropics.

Some of the silica—and other elements—in forest litter is recycled, and some of it is dissolved and enters groundwater circulation; under favorable conditions, however, substantial quantities of silica must be pumped out of the ground at depth, spread over the surface in organic debris, and then swept off by erosive agents.

Although I have taken silica as an example, it is, of course, evident that the accumulator plants that select aluminum in preference to silica would tend to deplete the soil of this element and leave the ground enriched in silica. Hutchinson (*5*) has described many aluminum-accumulator plants, several of which would apparently be competent to change materially the ratio of alumina to silica in the soil if the plant community contained a preponderance of them and a dearth of silica accumulators. The quantitative aspects of the process suggested above must remain speculative until field studies are made in suitable areas, but the entire geobiochemical history of silica—and of other elements taken up by accumulator plants—is one of great interest and seems worthy of further investigation (*6*).

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14 March 1958

Long-Lived Cobalt Isotopes Observed in Fallout

It has generally been assumed that the long-term radiological hazards due to fallout from a nuclear detonation depend primarily upon the long-lived fission products. However, other radioactive products which are not derived from fission reactions may be present in fallout and may contribute to the hazard. These latter products would be created by neutron activation of elements in the immediate vicinity of the detonation. The presence of one such product, Co^{60}, has been indicated by analyses of fallout material (*1*) and of biological specimens recovered from fallout areas (*2*).

The investigation discussed in this report, which was carried out to determine the amounts of Co^{60} in fallout samples from the 1956 test series, revealed the existence of two additional cobalt nuclides, Co^{57} and Co^{58}. The amounts of these nuclides were determined. To permit assessment of the relative internal hazards from the cobalt isotopes, determinations of Sr^{90} were made on the same samples. From these data the Co^{60}/Sr^{90}, Co^{58}/Sr^{90}, and Co^{57}/Sr^{90} ratios were derived. Since all three cobalt isotopes emit gamma radiation, they would also contribute to an external hazard. The amount of this hazard was estimated by summing the photon energy release per unit time from the observed amounts of radiocobalt and comparing this value with similar values calculated for the associated fission products.

Radiochemical analyses were carried out on three samples of fallout obtained after one detonation of the 1956 nuclear weapon test series in the Marshall Islands. The samples consisted of large trays which had been exposed at various locations within the fallout pattern. After removal of the radioactive material and solution by acid treatment, aliquots were taken for strontium and cobalt analyses.

After the addition of strontium carrier and Sr^{85} (used as a tracer for chemical yield determinations), the strontium was separated by precipitation with fuming nitric acid and determined finally as the oxalate (*3*). The oxalates were dried and mounted for beta counting. The Sr^{90} was determined by measurement of the growth of the daughter, Y^{90}. The samples were quantitatively redissolved, and the chemical yield was determined through a gamma-ray spectrometer measurement of the remaining Sr^{85} tracer. After application of the usual corrections, the number of Sr^{90} atoms present at zero time was determined; a half-life value of 27.7 ± 0.4 years was used (*4*).

Cobalt was separated by adaptation of existing procedures (*3*). Since Mn^{54} was known to be present, manganese carrier

Table 1. Ratios of abundance of cobalt atoms to abundance of Sr^{90} atoms at zero time.

Item	Co^{60}/Sr^{90}	Co^{57}/Sr^{90}	Co^{58}/Sr^{90}
Sample A	0.323 ± 0.106	0.051 ± 0.017	0.027 ± 0.020
Sample B	0.245 ± 0.102	0.038 ± 0.013	0.021 ± 0.015
Sample C	0.255 ± 0.090	0.040 ± 0.013	0.022 ± 0.016
Avg. values	0.274	0.043	0.023
Avg. errors	± 0.100	± 0.014	± 0.017

was added (*5*). After a hydroxide scavenging from an ammoniacal solution, the supernatant solution was treated with H_2S. The resulting precipitate was extracted with a Na_2SO_4–$NaHSO_4$ solution to remove manganese. The cobalt was alternately precipitated several times as the hydroxide and cobaltinitrite. Chemical yield was determined by weighing the cobaltinitrite.

The cobalt yields were dissolved and analyzed for gamma activities by means of a single-channel gamma pulse-height analyzer. The presence of Co^{60}, Co^{57}, and Co^{58} was established by identification of their respective photopeaks, by comparison with standards of known energy.

The disintegration rate of each cobalt isotope was obtained by analysis of photopeak areas. After determination of the total pulse-height distribution, a standard of Co^{60} was prepared to equal the magnitude of the Co^{60} photopeaks of the isolated cobalt. This Co^{60} pulse-height distribution was subtracted from the total distribution. This subtraction of the Co^{60} Compton continuum permitted determination of the Co^{57} and Co^{58}. Their disintegration rates were computed from experimentally determined gamma-ray efficiencies and consideration of their respective decay schemes (relative photon abundance, internal conversion, and so on) (*6*). Figure 1 shows the pulse-height distribution of the separated cobalt and the spectrum of the Co^{60} standard. The 0.84-Mev Mn^{54} photopeak is shown as an energy reference.

The quantities of the isotopes Co^{57}, Co^{58}, and Co^{60} and the fission product Sr^{90} (and its precursors) in each of the samples at zero time were in the order of 10^{10} to 10^{12} atoms. These values were used to compute the Co^{57}/Sr^{90}, Co^{58}/Sr^{90}, and Co^{60}/Sr^{90} ratios listed in Table 1. The errors associated with these values are those produced by all determinate errors present in the calculations—that is, counting error, pipetting error, errors in chemical yield, and so on. The average values show the average error of the three measurements.

The ratios shown in Table 1 indicate that significant amounts of radiocobalt were formed relative to Sr^{90}. Possible reactions for the formation of the cobalt nuclides from environmental nickel and cobalt are:

$$Co^{59}(n,\gamma)Co^{60}$$
$$Ni^{60}(n,p)Co^{60}$$
$$Co^{59}(n,2n)Co^{58}$$
$$Ni^{58}(n,p)Co^{58}$$
$$Ni^{58}(n,2n)Ni^{57} \xrightarrow[K]{\beta +} Co^{57}$$

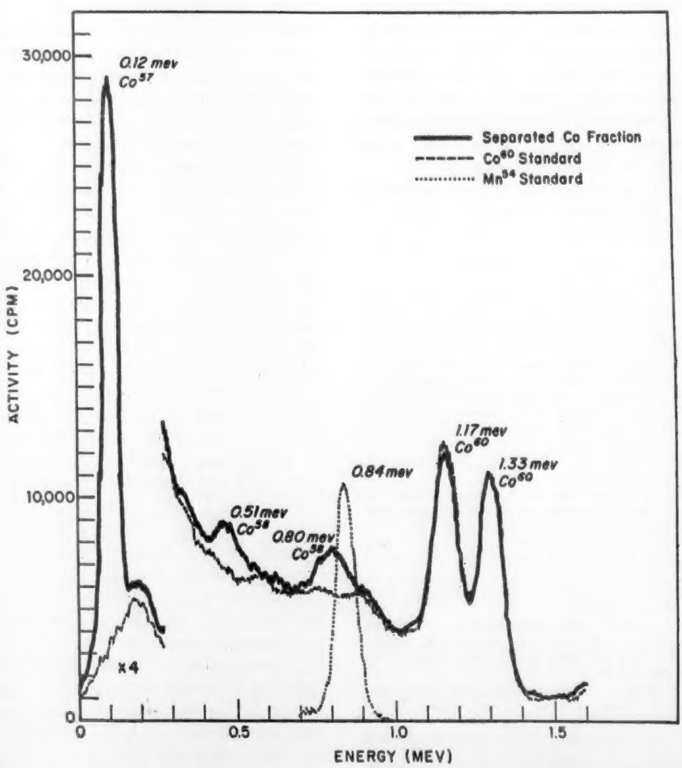

Fig. 1. Comparison of pulse-height distribution of separated cobalt sample with distributions of reference standards.

The biological hazards resulting from fallout may be placed in two categories: (i) the internal hazard caused by ingestion and inhalation of active material and (ii) the external hazard caused by penetrating radiation the source of which is external to the body.

If material the ratios of whose atoms are those found in Table 1 were ingested or inhaled, the hazard due to the presence of the radiocobalt would be negligible as compared to that from the Sr^{90}. This is evident when, among other factors, the biological half-lives (3.9×10^3 days for Sr^{90}; 8.4 days for Co^{60}) (*7*) and the ionizing radiation emitted (β for Sr^{90}; primarily γ for Co^{57}, Co^{58}, and Co^{60}) are compared.

External hazard in fallout may be considered to be that primarily due to gamma radiation. This hazard is a function of photon energy, scattering, absorption, and so on. The net effect, however, of these factors for fallout situations (approximated by uniformly contaminated fields) is that the hazard is roughly proportional to energy release per unit time. Values of gamma energy released per second (μ_1) of fission products resulting from 10^4 fissions have been computed for times up to 1.2×10^3 yr after time of fission (*8*). The values so obtained may be compared over the same time period with the energy released per second (μ_2) by the quantities of radiocobalt found associated with 10^4 fissions. This ratio μ_2/μ_1, in percent, is found to be 0.14 at 9.8 days, 31 at 1.20 yr, 149 at 2.6 yr, 211 at 5.6 yr, and 26 at 25.7 yr. These values represent the analyses of a limited number of samples from one detonation. It is evident, however, that radiocobalt pro-

duced in the ratios given in Table 1 would constitute a considerable portion of the external hazard of fallout, particularly at times greater than 1 yr.

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7 July 1958

Ontogeny of Hemoglobin in the Skate Raja binoculata

In all sufficiently studied mammals, the fetus has a hemoglobin that is biochemically distinct from that of the adult (*1*). Ontogenetic changes in the hemoglobin are found also in the chicken (*2*), the terrapin (*3*), the bullfrog (*4*), and the teleost fish *Scorpaenichthys* (*5*). The possibility that a developmental sequence of at least two hemoglobins is characteristic of the vertebrates appears to be contradicted by McCutcheon's failure to find any difference between the hemoglobin of adult and fetal viviparous rays (*3*). However, McCutcheon states: "The lack of early stages in the collections leaves open the possibility of an early developmental Hb [hemoglobin] with a higher affinity [for oxygen] than fetal and adult Hb." Because a few egg-cases of the barn-door skate *Raja binoculata* were collected during otter-trawling, it was possible to study the oxygen equilibrium of hemoglobin solutions and erythrocyte suspensions (equivalent to blood) of this oviparous elasmobranch in individuals of various ages (*6*).

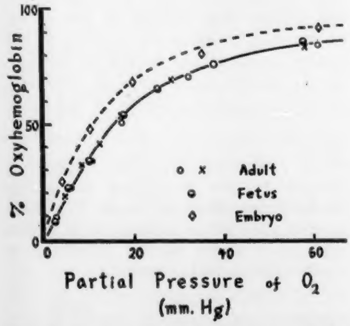

Fig. 1. Oxygen dissociation curves of hemoglobin solutions prepared from blood of adult (approximately 100 kg), fetal (9 g), and embryonic (1.5 g) skates. Conditions: 1.5 percent hemoglobin in potassium phosphate buffer; final ionic strength, 0.267; pH, 6.50 to 6.58; temperature, 10°C. Crosses represent a solution of adult hemoglobin subjected to a second analysis 48 hours after the original determination of the oxygen equilibrium.

A comparison of oxygen dissociation curves of adult, fetal, and embryonic hemoglobin is shown in Fig. 1. From such data one can calculate (*7*) the two constants of the Hill approximation: p_{50} is the oxygen tension at which there are equal quantities of oxygenated and deoxygenated hemoglobin; and n is a measure of the heme-heme interactions. The parameter n determines the shape of the oxygen dissociation curve, and p_{50} determines the position of the curve. Figure 2 shows the variation of these two constants as functions of pH for skate hemoglobin inside and outside the erythrocyte. From the information presented in these figures it can be concluded that fetuses (wet weight 9 to 27 g) and adults (to 100 kg) have hemoglobin with the same oxygen equilibrium.

This finding parallels the studies of McCutcheon on viviparous rays (*3*). However, the hemoglobin of three embryos (wet weight 1 to 1.6 g) possessed a slightly higher oxygen affinity in both erythrocyte suspensions and hemoglobin solutions; furthermore, for this possible "embryonic hemoglobin," heme-heme interaction was almost completely removed by hemolysis and subsequent dilution, whereas the same treatment did not alter "fetal and adult hemoglobin" in this respect. It is entirely possible that some adult hemoglobin was present along with the embryonic hemoglobin; however, since n for hemoglobin solutions obtained from the embryos was 1.1, as opposed to $n = 1.5$ to 1.8 for adult and fetal hemoglobin in solution, one can calculate, assuming that n cannot be less than 1.0 for embryonic hemoglobin and that no embryonic hemoglobin is present in adult skates, that at least 80 percent of the hemoglobin present in these embryos is of a distinct type. Further experimentation is limited by the scarcity of egg-cases and the small quantity of hemoglobin available from embryos (0.2 ml of a 1.5 percent hemoglobin solution from a 1.6-g embryo).

Since the skate egg-case, in which the embryos and fetuses remain for 1.5 to 2 years of development, is relatively isolated from the environment except for the diffusion of respiratory gases (the "cleidoic" condition) (*8*), it might be expected that hemoglobin with high oxygen affinity would be needed throughout not only the embryonic but also the fetal period, in contrast to observed results. However, observations on ten egg-cases indicated the egg-case is a "closed system" only during the first few months of development. When the egg-case is laid, a hole (2 by 4 mm) at each of the four corners is plugged with a very viscous mucus, which is gradually dissolved during development. In all fetuses with adult hemoglobin, the four holes were open; in the embryos weighing 1 to 1.6 g, only two of the holes were still plugged. The oxygen tension [polarographically determined (*9*)] inside these egg-cases was rarely less than half that of sea-water. The urea retention function of the skate egg-case (*8*) must take place only during the initial phases of development, although even small embryos

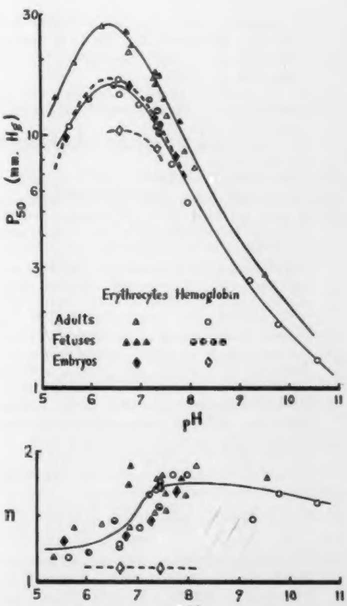

Fig. 2. Oxygen affinity (top) and heme-heme interaction (bottom) as functions of pH for the hemoglobin in solution and in erythrocytes for adult, fetal, and embryonic skates. Conditions: 1.5 to 2 percent hemoglobin solution in potassium phosphate buffer; final ionic strength, 0.267; erythrocyte suspensions in elasmobranch Ringer's solution; temperature, 10 to 11°C.

(wet weight 0.5 g) survived for weeks in running sea-water. The function of the egg-case for the entire 1.5-to-2 year period is protection of the embryo and the external yolk sac from injury; only when the external yolk sac is completely absorbed does the young skate hatch. In contrast to the transient existence of "embryonic hemoglobin" in the oviparous skate, the ovoviviparous shark *Squalus suckleyi* has a distinct fetal hemoglobin throughout its 23-month gestation period (*10*).

The widespread phylogenetic distribution of the ability to synthesize a fetal or embryonic hemoglobin of high oxygen affinity in egg-laying vertebrates (skate, bullfrog, terrapin, and chicken) represents a biochemical "preadaptation" (*11*) which has made possible the development of the oxygen-transfer system involved in the diffusion of oxygen from maternal to fetal blood (*1*) in the polyphyletic evolution of ovoviviparty and viviparity in many vertebrate groups.

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17 January 1958

Density of the Upper Atmosphere

An atmospheric density at an altitude of about 368 km has been inferred from the orbital behavior and physical characteristics of the American artificial earth satellite Explorer I, also denoted as 1958 Alpha. The orbital data as of 1 February 1958 were (*1, 2*): eccentricity, 0.139; inclination, 33°.2; argument of perigee, 120°.0; anomalistic period, $0^d.0798274$; decrease of period 3.9×10^{-7} day per period or about $0^s.42$ per day. From these one finds a mean distance of 1.22757 earth radii, corresponding to a perigee height above the international ellipsoid of 368 km.

The satellite is a cylinder 80 in. long and 6 in. in diameter, and it has a mass of about 14 kg (*3*). The area of such an object that is relevant to its air resistance is its area projected on a plane normal to its direction of motion. The average over all possible orientations, for random tumbling, is one fourth of the total superficial area, or 2520 cm^2. The same value is obtained if the cylinder spins about a transverse axis, randomly oriented with respect to the orbit plane. Averaged over a spin period, over orientations of the spin axis with respect to the orbit plane, and over the motion of perigee, the same projected area has been obtained as for random tumbling, and has been employed. The aerodynamic drag coefficient has been taken to be 2. The density has been inferred by a method described elsewhere (*4*) from this value, the mass, the average area, the eccentricity, the mean distance, the rate of decrease of period, and the logarithmic derivative of density near perigee given by the ARDC model atmosphere (*5*).

The density thus found, 1.5×10^{-14} g/cm^3 at a geometric altitude of 368 km (348 geopotential) is about 14 times that predicted by the ARDC model atmosphere. It falls nearly on the middle curve, No. 2, in a study (*6*) that tentatively suggested a modification of the ARDC atmosphere to satisfy a density 4.5×10^{-13} g/cm^3 at 220 km (213 geopotential) that had been inferred (*7*) from observations of the U.S.S.R. satellite 1957 Alpha 2. This value was about 9 times the ARDC density. The values 4.5×10^{-13} and 1.5×10^{-14} g/cm^3 depend somewhat on the gradients of density of the ARDC model employed in the reductions. It seems better to infer the densities at both altitudes from the observations without recourse to model atmospheres, and to proceed by successive approximations until the gradients and densities are consistent. In this way, from the observations of both satellites together, densities have been inferred of about 4.0×10^{-13} g/cm^3 at 220 km and about 1.4×10^{-14} g/cm^3 at 368 km. These values do not agree well with densities predicted by Harris and Jastrow (*8*) as extrapolations from altitudes of about 220 km and below, but they seem to be in surprisingly good agreement with curve No. 2 of reference (*6*).

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24 March 1958

Density Determinations Based on the Explorer and Vanguard Satellites

Minitrack observations on the orbits of Explorer I and Vanguard I permit us to make a rough determination of the density of the atmosphere at latitudes between 33°N and 33°S (*1, 2*). Our analysis is based on the orbit elements and rate of change of period obtained from Minitrack data for these satellites by the Vanguard Computing Center. The change in period is the direct result of the drag exerted by the atmosphere, which causes the satellite to lose energy continuously during its lifetime. As the energy of the satellite decreases, it falls towards the center of the earth,

Table 1. Orbital periods for Explorer I, derived by the Vanguard Computing Center from Minitrack data. The third column gives the average value of dP/dt, obtained from the tabular differences in the first and second columns.

Date	P (min)	dP/dt (min/day)
5 Feb.	114.95	
		0.0073
2 Apr.	114.54	
		0.0097
2 May	114.25	
		0.0150
17 May	114.13	
Weighted av. (min/day)		$(9^{+6}_{-3}) \times 10^{-3}$
M/C_dA		(24 ± 8) kg/m^2

reducing its average altitude and therefore the time required to complete each circuit. Detailed calculations, based on the equations of satellite motion, then determine the quantitative relation between the reduction in the period and the average air density in the orbit.

Since the density falls off very rapidly with increasing altitude, the average density in the orbit is heavily weighted by the contributions near perigee. Our calculations indicate that for both satellites, as also in the case of Sputnik I (*3*), the rate of change of period actually determines the density at an altitude approximately 50 km above perigee.

Tables 1 and 2 list the anomalistic periods and corresponding rates of change of period for the Explorer I and Vanguard I satellites, as issued by the Vanguard Computing Center. The tables also give the estimated values of the ballistic drag parameter, M/C_dA (M = satellite mass, A = satellite area projected along the direction of motion, and C_d = drag coefficient). We note that the observed rate of change of period determines only the ratio of the density to the ballistic drag parameter, hence a knowledge of this parameter is essential for the density analysis. The large probable error indicated in the value of M/C_dA for Explorer I represents the uncertainty in the cross-sectional area of that satellite. Explorer I has a cylindrical shape with a length of 203 cm and a radius of 7.3 cm, and the maximum and minimum values of its projected area may therefore vary by a factor of 20, depending on the orientation of the cylinder relative to the direction of motion. In our analysis the projected area is estimated by averaging over all orientations of the satellite, but a proper calculation of the effective area is extremely complicated in the present case because the motion of Explorer I about its center of mass cannot be properly described by either a random tumbling or a uniform precession about a fixed spin axis (*4*). We consider our estimate of the projected area to be uncertain by a factor of 2.

Table 3 gives the densities which we obtain from the time-weighted averages of dP/dt in Tables 1 and 2, together with the altitudes to which these densities refer. The probable errors in the average density represent the combined effects of the uncertainty in area and the variations in dP/dt during the period covered by the observations. The densities in Table 3 correspond to a mean scale height of (73 ± 10) km and a mean temperature of 1250° ± 200°K for the region between 400 and 700 km.

Although the density value based on Explorer I has a large probable error, this result is still of substantial interest because, when it is combined with the Vanguard I density, it gives us an indication of atmospheric conditions in a latitude region not covered by the results from Sputnik I and the earlier rocket flights. The perigee of Sputnik I was located at a latitude of 39° ± 6°N during the period on which the density analysis of that satellite was based, and the rocket data which we combined with the sputnik value were obtained at latitude 33°N. On the other hand, the orbits of the Explorer and Vanguard satellites are confined to the region centered on the equator and lying between 33°N and 33°S. Since perigee rotates at the rate of 6° per day in the orbital planes of these satellites, the average densities for the intervals covered in Tables 2 and 3 constitute a thorough sampling of all latitudes in this region. Thus the combination of rocket and Sputnik I data describes a temperate-zone atmosphere, while the Explorer and Vanguard results refer to a band of latitudes centered about the equator.

According to recent results of LaGow at 200 km (*5*), the summer day-time density at 59°N is 8 times the corresponding density at 33°N. We expect comparable differences between the present results and our earlier model for temperate latitudes, but in fact the densities of Table 3 are only 30 to 50 percent less than the lower limit of probable error in the temperate zone atmosphere (model *a* of reference *2*). Presumably the comparison must also allow for diurnal and seasonal variations, which are as yet very poorly determined.

As a corollary to the preceding remarks, it is interesting to note that because of the strong latitude dependence of upper atmosphere densities, we cannot compare density determinations based on the orbits of the present United States satellites with those obtained from U.S.S.R. satellites.

Table 2. Orbital periods for Vanguard I, derived by the Vanguard Computing Center from Minitrack data. The third column gives the average value of dP/dt, obtained from the tabular differences in the first and second columns.

Date	P (min)	dP/dt (min/day)
1 May	134.277	
		$(3.0 \pm 0.5) \times 10^{-4}$
7 June	134.266	
		$(2.8 \pm 0.8) \times 10^{-4}$
25 June	134.261	
Weighted av. (min/day)		$(3.0 \pm 0.6) \times 10^{-4}$
M/C_dA		(24 ± 8) kg/m^2

Table 3. Densities derived from satellite data.

Altitude (km)	Density (g/cm^3)
405 (Explorer I)	$9^{+6}_{-4} \times 10^{-15}$
720 (Vanguard I)	$(1.2 \pm 0.3) \times 10^{-16}$

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4. The use of the average cross section is clearly appropriate for random tumbling. If the cylinder spins about a fixed axis the average will still be applicable to observations spread over a period of one or more months, because of the rapid motion of the perigee in the orbital plane. In fact, however, the spin axis of Explorer I is not fixed. This satellite is aerodynamically stable, and air drag exerts a torque about its center of mass on each passage through perigee, tending to align the spin axis with the direction of motion at perigee.
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14 July 1958

Growth Promotion in Pea Epicotyl Sections by Fatty Acid Esters

The growth of excised pea epicotyl sections is less than that of a similar section left on the intact plant, even if optimum concentrations of indole acetic acid (IAA), gibberellic acid (GA_3) (*1*), sucrose, and cobalt (*2*) are supplied. In an investigation (*3*) of this failure of excised sections to grow optimally, fatty acid esters have been found to bring about section growth promotions much larger than any previously reported in this standard auxin bioassay material.

The peas used were the customary bioassay variety, Alaska, and the dwarf variety, Laxton's Progress. The technique utilized was essentially that of Christiansen and Thimann (*4*), except that ten 10-mm sections were employed in 20 ml of solution, a rotary shaker was employed, the pH was 5.5, and, in the case of the dwarf pea, sections were cut at 6 days of age. Since it is especially necessary that the dwarf pea receive a standard amount of red light during development, a continuous illumination of about 0.3 erg/cm^2/sec was supplied from a 1-watt neon bulb filtered through ⅛-inch thick pieces of No. 2444 red and No. 2082 green Plexiglas.

Pea sections so prepared showed a large increase in growth over that of con-

Table 1. Dependence on auxin of the pea fraction response. Percentage increase in length of 10-mm subapical sections of third internode of Laxton's Progress pea seedlings taken at 6 days of age, after 24 hours in 1.25 percent sucrose + $5 \times 10^{-5}M$ $CoCl_2$ + $5 \times 10^{-3}M$ KH_2PO_4 (*p*H 5.5), and additives as listed. Standard deviations are cited. All solutions initially 0.2*M* in acetonitrile.

Additive and amt. (mg/lit.)	No pea fraction	40-mg/liter pea fraction
Controls	29.7 ± 5.3	16.6 ± 2.5
GA_3 (0.1)	30.6 ± 3.6	25.5 ± 7.0
IAA (0.3)	51.2 ± 6.0	61.5 ± 5.4
GA_3 (0.1) and IAA (0.3)	58.7 ± 17.7	94.3 ± 10.1

trols when boiling ethanol extracts of dwarf or Alaska pea seeds, epicotyls, roots, or tips were added to the bioassay solutions. This growth response (Fig. 1*A*), as large as 130 percent above initial length in some other experiments, was markedly greater than that produced by adenine, uracil, and certain amino acids (*5*). But the growth of the sections was still not entirely restored to that of the intact plant, on which comparable sections grow about 140 percent for the dwarf and some 200 percent for the Alaska pea in the same period.

The ethanol extract of Alaska pea seeds was concentrated by dialysis, extraction of the nondialyzables with benzene, and vacuum distillation of the resulting benzene extract (bp 140° to 160°C at pressure of about 0.1 mm-Hg). This pea fraction is apparently largely a mixture of glycerides, and its further study was hampered by its insolubility in water. Tests of detergents to disperse it led to the surprising discovery that Tweens 20, 80, and 81 (*6*) had activity themselves; this activity was nearly as large as that of the fraction isolated from peas (Fig. 1*B*). To obviate this difficulty, acetonitrile was adopted as a dispersing agent. At concentrations less than 0.3*M*, it was found to be physiologically inert, and its presence had no marked modifying influence on the results reported here.

Some of the Tweens have been shown previously to promote specifically the growth of *Lactobacillus* (*7*) and of a *Venturia* mutant (*8*). In these lower plants, the effect of the Tweens was traced to their content of unsaturated fatty acids, but it was also mimicked by biotin. In peas the growth obtained with methyl linoleate was as great as that obtained with the isolated natural fraction, although the optimum was sharper—that is, high concentrations were more inhibitory; methyl oleate was also active (Fig. 1*C*), and methyl linolenate behaved similarly. But unlike the response in lower plants, the response in peas was not notably *p*H-sensitive, and biotin was completely inactive on peas. It also differed in that saturated fatty acid esters produced a response. The saturated esters are less satisfactorily studied quantitatively because of dispersion problems.

A wide range of other vitamins, yeast extract, kinetin, traumatic acid, diphenyl urea, adenine, uracil, uridine, cytidine, glycerol, triacetin, batyl alcohol, and lecithin failed to produce comparable elongations, nor have any of these compounds yet been shown to enhance significantly the response to the fatty acid esters. It seems likely, therefore, that the activity of the isolated pea fraction can be largely, if not entirely, attributed to its content of fatty acid esters, rather than to a specific glyceride.

Other peas, the dwarfs Progress No. 9 and Little Marvel, were also shown to respond to the pea glyceride fraction. In growth of *Avena* coleoptile sections, on the other hand, no significant effect except inhibition by the pea fraction or by unsaturated acid esters has been noted in any test to date.

The effect of the isolated glyceride fraction and of methyl linoleate is apparently to promote the sensitivity of the pea sections to IAA. The pea fraction alone is ineffective or inhibitory. In the presence of GA_3 alone it has a very small effect, while in the presence of both IAA and GA_3 its maximum effect is exhibited (Table 1). Even larger promotions can be noted in other experiments (Fig. 1).

The quantitative relations suggest that a hormonal rather than a gross nutritive role is played by the acid esters. Sections from Laxton's Progress peas give optimal growth in $2 \times 10^{-6}M$ IAA and $7 \times 10^{-5}M$ methyl linoleate or oleate. Sections from Alaska peas at this IAA level (which is suboptimal for them) respond optimally to methyl linoleate at $3 \times 10^{-5}M$. The effective ester concentrations must actually be less since it has been necessary to supply these compounds as an acetonitrile dispersion and not as a true solution. The esters are thus effective in quantities at most only 20 to 35 times larger than that of the hormone, IAA. This suggests a close relationship of auxin activity to lipid metabolism, a conclusion fortified by the results of Christiansen and Thimann (*4*), who found that inhibition of lipid utilization in pea sections paralleled inhibition of growth, and which has also been advanced on less direct grounds by Bennet-Clark (*9*).

These experiments indicate a need for a reassessment of the conditions for the pea-section auxin bioassay. They also confirm that dwarf peas are similar in auxin response to standard peas (*10*).

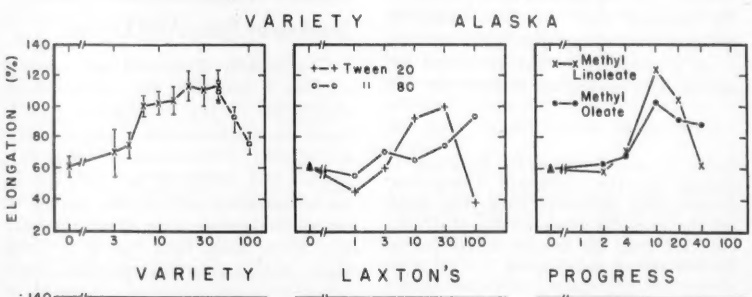

Fig. 1. Growth of two varieties of pea epicotyl sections in various fatty acid esters. All sections were grown in 1.25 percent sucrose + $5 \times 10^{-5}M$ $CoCl_2$ + $5 \times 10^{-3}M$ KH_2PO_4 (*p*H 5.5) + 0.3 mg of IAA per liter + 0.1 mg of GA_3 per liter; these conditions provide maximum growth of Laxton's Progress peas. Percentage increase in length over the initial 10-mm section after 24 hours is plotted against concentration in milligrams per liter, the latter being a log scale. *A*, Pea fraction isolated as in text. Standard deviations indicated by bars. Crosses and circles indicate separate experiments. *B*, Plus marks, Tween 20. Circles, Tween 80. *C*, Crosses, methyl linoleate. Dots, methyl oleate. In *A* and *C*, the solutions also initially contained 0.25*M* acetonitrile.

However, in the case of gibberellic acid, which has so large an effect on intact peas and only a small effect on excised sections (*11*), this investigation has failed to show any specific promotion of GA_3 action by any extract or additive tested. These facts suggest that the analysis of accessory growth factors, such as the "calines" proposed by Went (*12*), has continuing pertinence in the study of plant growth (*13*).

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27 March 1958

Action of Salicylate on Metabolism of Acetate-2-C^{14} in the Rat

Salicylates have been shown to uncouple oxidative phosphorylation reactions in mitochondrial preparations (*1*), and this action may explain the increased oxygen consumption observed after the administration of salicylates to man (*2*) and to the rat (*3*). It may also be related to some of the effects of salicylates on carbohydrate metabolism in animals and isolated tissues. Thus, although an increased rate of glycogenolysis due to release of adrenaline is an important factor (*4*) in the depletion of glycogen caused by salicylate in the normal rat (*5*), impairment of glycogenesis due to an inadequate production of energy-rich phosphate bonds may also be concerned, particularly since salicylate diminishes glycogen synthesis in isolated rat-liver slices (*6*). The hypoglycaemic action of salicylate in the alloxan-diabetic rat (*7*) may also be interpreted as resulting from defective carbohydrate synthesis.

Table 1. Effect of salicylate on the incorporation of C^{14} in the liver glycogen and on the excretion of $C^{14}O_2$ and $C^{12}O_2$ in the breath of rats given acetate-2-C^{14}. Results are expressed as means plus or minus standard deviation. The significance of the differences between the means of the control and salicylate groups has been analyzed by the *t* test, and values of *P* are included.

Rats (No.)	Liver glycogen d.p.m./mg. (disintegration/min mg)	Total CO_2 [(0–60 min) mg/min]	$C^{14}O_2$ Cumulative % injected dose (0–60 min)	Specific activity of total CO_2 (μc/g) C/10 μc injection		
				10 min	30 min	60 min
			Control			
6	5193 ± 1640	7.32 ± 0.45	32.94 ± 2.01	2.43 ± 0.20	3.48 ± 0.37	2.28 ± 0.19
			Salicylate (500 mg/kg)			
4	20 ± 12.5 $P = 0.01$	14.70 ± 1.52 $P = 0.01$	52.27 ± 3.93 $P = 0.01$	1.87 ± 0.24 $P = 0.2$	3.50 ± 0.35 $P = 0.9$	1.42 ± 0.17 $P = 0.05$
			Salicylate (250 mg/kg)			
4	60 ± 18 $P = 0.01$	9.25 ± 0.40 $P = 0.02$	48.22 ± 4.33 $P = 0.02$	2.05 ± 0.28 $P = 0.4$	4.26 ± 0.41 $P = 0.3$	2.17 ± 0.13 $P = 0.8$

The effect of salicylate on the appearance of C^{14} in the liver glycogen and expired CO_2 of rats given acetate-2-C^{14} has been studied (*8*). Male rats of the Long-Evans strain, weight 200 to 250 g, were fasted for 24 hours and given 3 millimoles of sodium lactate by stomach tube at the beginning of the experiment. Thirty minutes later they received sodium salicylate by intraperitoneal injection; acetate-2-C^{14}, approximately 10 μc per rat, was administered by the same route after a further 30 minute interval. The radioactivity and CO_2 content of the breath were measured for 1 hour by the continuous recording equipment described by Tolbert, Kirk, and Baker (*9*). The rats were then killed by an intraperitoneal injection of Nembutal, the liver was excised, and the liver glycogen was isolated by the method of Marks and Feigelson (*10*) and purified to constant specific activity according to the directions of Stetten and Boxer (*11*).

The results, given in Table 1, show that salicylate, in a dose of either 250 mg or 500 mg/kg of body weight, inhibited the incorporation of C^{14} into liver glycogen after the injection of the labeled acetate. The higher dose of salicylate caused significant increases in both the $C^{12}O_2$ and the $C^{14}O_2$ but did not change the specific activity of the total CO_2. A similar but less marked pattern was observed with the lower salicylate dose.

The major pathway by which acetate carbons are incorporated into liver glycogen is via acetyl-coenzyme A, the Krebs cycle, decarboxylation of oxaloacetate to give phosphopyruvate, and the modified reversal of the Embden-Meyerhof scheme of glycolysis (*12*) and energy-rich phosphate bonds are necessary at various intermediate steps. The virtual absence of radioactivity in the liver glycogen of the salicylated animals, therefore, is consistent with the view that salicylate impairs carbohydrate synthesis by interfering with the production of energy-rich phosphate bonds. It has been emphasized by Weinman, Strisower, and Chaikoff (*12*) that the mere demonstration of incorporation of isotope into glycogen does not necessarily mean that a net synthesis of glycogen from a labeled fatty acid has occurred. These workers consider that glycogen synthesis from acetate is made possible only by an additional (that is, nonacetate) influx of Krebs cycle intermediates into the cycle. The administration of lactate to the animals in the present work could provide such an influx and make possible the net increase of glycogen via the synthetic reactions outlined above.

The increased excretion of $C^{12}O_2$ and $C^{14}O_2$ in the breath of the salicylated rats may be a direct result of the well-known action of salicylate in causing hyperventilation by stimulation of the respiratory center. However, a contributory factor may be an increased substrate breakdown as a consequence of inefficient phosphorylation mechanisms.

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10 April 1958

Letters

Darwin and Pandora's Box

A report on evolution by T. Dobzhansky [*Science* **127**, 1091 (1958)] discusses the persistence of popular interest in this subject. Dobzhansky cited evidence from his own experience that, in the 100 years since Darwin announced his views, interest in evolution had spread all over the world, from Punta Arenas to the Egyptian desert. In the reference article, Dobzhansky concluded that evolution had as one of its consequences the extinction of all species. That is, for the species, the steps of evolution, existence, and extinction parallel the birth, life, and death of the individual. He states that "no biological law can be relied upon to insure that our species will continue to prosper, or indeed that it will continue to exist."

The conclusion should be considered in the light of the impact on human behavior of our knowledge of human mortality. The fact that the increased intelligence of *Homo sapiens* led to a knowledge of the inevitability of death is an element of anthropology. Carleton S. Coon treats this subject in terms of the myth of Pandora's box. As part of the search for knowledge, the box was opened, and knowledge of death came out. "One way, and one way only, permitted man to retain his peak efficiency with this problem on his mind—the belief in life after death" [*The Story of* Man (Knopf, New York, 1954), page 67].

One form that this belief has taken has been a reliance on immortality through one's descendents—through the persistence of the species. Yet one consequence of the understanding gained from our concept of evolution is the knowledge that species become extinct—not just occasional species, as an odd incident, but all species, inevitably, as part of the order of things. Dobzhansky says: "Man has gained some knowledge which is a basis for hope that the problem of the ultimate extinction of *Homo sapiens* is not impossible of solution." Even so the wise men of prehistory who first perceived the universality of individual mortality must have hoped to find a way to avoid its personal application.

Popular interest in the findings of astronomers since Copernicus and of biologists since Darwin has focused on the question: "Is our planet or our species, by some exceptional chance, immortal?" Isaac Asimov says, in considering the wellspring of science fiction, "There used to be the consolation that even though we, as individuals, might die, life would continue, spring would come, flowers would bud. But now we have brought ourselves to such a pass that we wonder whether the planet itself might not die with us." [R. Bretnor, Ed., *Modern Science Fiction: Its Meaning and Its Future,* (Coward-McCann, New York, 1953), p. 188]. And in point of fact, extinction of our species can, on probability, be expected much sooner than annihilation of our planet.

Homo sapiens has had less than a century to adjust to the concept of species mortality that came from the Pandora's box opened by Darwin. Man's search for a way "to retain his peak efficiency with this problem on his mind" continues, from Punta Arenas to the Egyptian desert.

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Publication versus Communication

A recent editorial, "Journal publication in microform" [*Science* **127**, 1145 (1958)] reminds us that science per se did not exist until communication was established among scientists. One of the most effective methods of communication was publication.

Publishing, or making public, brought with it a variety of problems. One of these, the productivity of scholars, is old (*1*); the other, editorial reduction of manuscripts, is relatively new (*2*). In fact, the editor was originally the publisher. The word is derived from *editus,* past participle of *edere,* to give out, put forth, publish. (*Editeur,* appearing as part of the title page in French books, still is used to designate the publisher). Originally, scholars wrote their manuscripts and brought them to printers, and the printers then published and sold them. The role of the editor of today is a refinement of this earlier and simpler process.

As a result of editorial selectivity, communication, "the blood-stream of science," is, in many cases, being slowed so greatly that cyanosis is apparent. In my own field, that of psychology, the overcrowding of journals with manuscripts suitable for publication has resulted in (i) a two-year publication lag; (ii) requests to condense manuscripts to a single page for publication; (iii) an elimination of all historical or theoretical material from papers intended for publication even as monographs; (iv) editorial fiats regarding the reduction of reference lists by 90 per cent. I have experienced all these restrictions.

Indeed, the situation has become so serious that communication often seems to actually be impaired by publication. The patient (science) can see one of his members (psychology) turning blue now if he looks. Possibly other parts are similarly affected.

A substantiating complaint comes

from a theorist who ascribed much of the criticism directed against his theoretical framework to a serious lack of understanding. "The major difficulty is that the studies have appeared only in experimental [psychology] journals in which space limitations have required that theoretical discussions be kept to a minimum" (*3*). Result? The theory has received only piecemeal presentation, and communication seems to have been hindered by publication.

In psychology a rule of thumb in regard to preparing manuscripts for publication has arisen: a journal article should be so written (because of rigid space requirements) that any problems another scientist may have in repeating the experiment should be capable of removal by the exchange of a maximum of two letters.

The *Science* editorial recognizes the need for restoring detail to scientific publication and suggests it be accomplished by microphotographic reduction of journals. Details eschewed in publication are needed for communication. True. But, I do not know whether microform journal publication is the best solution. As the editorial itself points out, such a method "has not as yet achieved success" despite demonstrated merits. I would suggest that consideration be given to auxiliary publication. At least two methods of auxiliary publication—that is, the guaranteed availability of materials that cannot achieve journal publication—exist and have been used successfully. These are: (i) library deposit; libraries that have interlibrary loan policies or that, for a fee, can make microfilm or photostatic reproductions are excellent auxiliary outlets; and (ii) the method used by the American Documentation Institute of the Library of Congress; the institute freely accepts, for reproduction, materials cited in published articles and prepares 35-millimeter film or 6-by-8-inch photocopies. In both cases, specific citations are necessary so that requests from communicants can be fulfilled.

Both methods of auxiliary publication would seem to help restore the function of communication to publication. Microform publication of journals may be too drastic a step. Reducing the blood-stream may be more damaging than diverting part of its flow. Other methods of restoring a healthy color, less experimental and already available, may serve as well.

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Meetings

Symposium on Fodder Plants, Poland

An International Symposium on Fodder Plants was held in Poznan, Poland, 25–28 June, under the sponsorship of the Institute of Plant Breeding of the Polish Academy of Sciences. S. Barbacki of the University of Poznan was the program chairman and presided at the symposium. The program was devoted to the genetic and other scientific factors, including chemistry, involved in the improvement by breeding of such forage crops as lupines, alfalfa, clovers of various kinds, and grasses. Fifty papers were delivered. These are being printed, with English summaries, in the Polish annual periodical *Roczniki Nauk Rolniczych.*

Attendance at the symposium totaled 160. Most of these were research workers in the various Polish universities and experiment stations. There were 17 participants from other countries, including two from the U.S.S.R., one from Great Britain, one from Hungary, two from Czechoslovakia, seven from East Germany, one from West Germany, two from Sweden, and one from the United States—Noble Clark of the University of Wisconsin. After the symposium, some of the visitors made a 6-day tour of research centers in Poland where laboratory studies and field experiments with forage crops are under way.

Rocket Society

Missile and rocket technology in the various armed services and in industry will be explored in Detroit, 15–18 September, at the national fall meeting of the American Rocket Society. Twenty-nine papers and a 6-member panel discussion are scheduled for presentation at eight technical sessions. There is one "secret" and one "confidential" session.

Among topics to be considered are both long- and short-range missiles; the impact of space flight on industry; controls for supersonic air-breathing engines, including ramjets; latest developments in monopropellants (confidential) and in auxiliary power supplies (secret); production methods for complete missiles and various components; and operational service problems. Participants from the armed services include Lieutenant General A. G. Trudeau, chief of research and development, Department of the Army; Major General J. H. Hinrichs, chief of ordnance, Department of the Army; George Valley, chief scientist, U.S. Air Force; and Major General John B. Medaris, commanding officer at the Army's Redstone Arsenal.

Planetarium Symposium

A symposium on planetaria and their educational uses will be held at Cranbrook Institute of Science, Bloomfield Hills, Mich., under the auspices of the National Science Foundation, 7–10 September. The discussions will be concerned with the broader objectives of astronomical instruction as well as with teaching techniques and equipment. Registration will be limited to 95 persons. For additional information address: Mr. James A. Fowler, Cranbrook Institute of Science, Bloomfield Hills, Mich.

Nuclear Congress

Preliminary plans for the Fifth Nuclear Congress, to be held in Cleveland, Ohio, 5–10 April 1959, have been announced by the Engineers Joint Council. As in the past, the congress will be composed of four parts: the Nuclear Engineering and Science Conference; the Hot Laboratories and Equipment Conference; the Atomic Energy Management Conference; and the Atomfair, at which nuclear equipment will be on display.

Clarke Williams of Brookhaven National Laboratory, chairman of the Nu-

clear Engineering and Science Conference, has announced that papers will be considered for inclusion in the 1959 program if summaries are submitted *before 1 October 1958*. Prospective authors should submit 300- to 500-word summaries of proposed papers to the secretary of any one of the sponsoring societies. A list of sponsoring groups is available from Engineers Joint Council, 29 W. 39 St., New York, N.Y.

Forthcoming Events

September

21–25. Differential Anthropology, 5th intern. cong., Amsterdam, Netherlands. (R. A. M. Bergman, Royal Tropical Inst., Linnaeusstraat 2A, Amsterdam.)

21–28. Poultry Science, 11th world cong., Mexico, D.C., Mexico. (E. Karpoff, Agricultural Marketing Service, USDA, Washington 25.)

22–24. Standards Engineers Soc., 7th annual, Philadelphia, Pa. (Standards Engineers Soc., Box 281, Camden 1, N.J.)

22–25. Scientific Instruments of the 16th to the 19th Century, symp., Frankfurt/Main, Germany. (International Union for the History and Philosophy of Science, 4, rue Thenard, Paris 5e, France.)

22–27. High-Speed Photography, 4th intern. cong., Cologne, Germany. (Royal Photographic Soc., 16 Princes Gate, London, S.W.7, England.)

23–25. Fat Research, 3rd intern. cong., Seville, Spain. (J. M. Martinez, Instituto de la Grasa, Avenida de Heliopolis, Seville.)

23–30. Rheology, 3rd intern. cong., Bad Oeynhausen, Germany. (R. S. Marvin, Rheology Section, Natl. Bureau of Standards, Washington 25.)

24–26. Mass Spectrometry Meeting, London, England. (R. A. Friedel, U.S. Bureau of Mines, 4800 Forbes St., Pittsburgh 13, Pa.)

24–28. Angiology and Histopathology, 3rd intern. cong., Venice, Italy. (L. Gerson, Intern. Committee on Angiology and Histopathology, 4, rue Pasquier, Paris, France.)

26–6. International Council of Scientific Unions, 8th general assembly, Washington, D.C. (W. W. Atwood, Natl. Research Council–Natl. Acad. of Sciences, Washington, D.C.)

28–2. Electrochemical Soc., semiannual, Ottawa, Ontario, Canada. (R. K. Shannon, 1860 Broadway, New York 23.)

29–1. Analytical Chemistry in Nuclear Reactor Technology, 2nd conf., Gatlinburg, Tenn. (C. D. Susano, Oak Ridge Natl. Lab., P.O. Box Y, Oak Ridge, Tenn.)

October

1–8. Speleology, 2nd intern. cong., Bari, Lecce, and Salerno, Italy. (F. Anelli, Castellana-Grotte (Bari), Italy.)

2–5. International Soc. of Audiology, 4th cong., Padua, Italy. (M. Arslan, 37, via Oltinate, Padua.)

2–6. International Soc. of Scientific Unions, 8th general assembly, Washington, D.C. (W. Atwood, Natl. Research

Council–Natl. Acad. of Sciences, 2101 Constitution Ave., NW, Washington 25.)

4–8. Hydrology and Climatology, intern. cong., Lacco Ameno and Ischia, Italy. (Segreteria del Comitato Organizzatore, Congresso Internazionale di Idrologia e Climatologia, Viale Castrense, 9, Roma, Italia.)

4–13. International Federation of Agricultural Producers, 10th conf., Brussels, Belgium. (IFAP, 1624 Eye St., NW, Washington, D.C.)

5–8. American Inst. of Mining, Metallurgical, and Petroleum Engineers, fall, Houston, Tex. (E. O. Kirkendall, AIME, 29 W. 39 St., New York 18.)

6–11. Electroencephalographic Study of the Higher Nervous Activity Processes in Animals and Man, colloquium (by invitation), Moscow, U.S.S.R. (Miss Mary A. B. Brazier, Massachusetts Neurophysiological Laboratory, Massachusetts General Hospital, Boston 14.)

7–9. International Soc. for the History of Pharmacy, cong., Venice, Italy. (A. F. Vitolo, Piazza Carrara 10, Pisa, Italy.)

8–12. Nutrition and Vital Substances, 4th intern. conv., Essen, Germany (Secretary General, Bemeroder Strasse 61, Hannover-Kirchrode, Germany.)

11–15. Salinity Problems in the Arid Zones, UNESCO symp., Tehran, Iran. (UNESCO, 19, avenue Kleber, Paris 16e, France.)

12–17. American Acad. of Ophthalmology and Otolaryngology, Chicago, Ill. (W. L. Benedict, 100 First Ave. Bldg., Rochester, Minn.)

13–15. Association of American Medical Colleges, 69th annual, Philadelphia, Pa. (W. Darley, AAMC, 2530 Ridge Ave., Evanston, Ill.)

13–15. National Electronics Conf., Chicago, Ill. (L. W. Von Tersch, Michigan State Univ., East Lansing.)

13–16. Society of Exploration Geophysicists, 28th annual intern., San Antonia, Tex. (C. C. Campbell, Box 1536, Tulsa 1, Okla.)

13–17. American Soc. of Civil Engineers, annual conv., New York, N.Y. (W. H. Wisely, ASCE, 33 West 39 St., New York 18.)

19–22. Land and water, Soil Conservation Soc. of America, 13th annual, Asheville, N.C. (H. W. Pritchard, executive secretary, 838 5th Ave., Des Moines 14, Iowa.)

19–24. American Soc. of Anesthesiologists, Pittsburgh, Pa. (J. E. Remlinger, 802 Ashland Ave., Wilmette, Ill.)

19–26. Allergology, 3rd intern. cong., Paris, France. (S. M. Feinberg, Medical School, Ward Memorial Building, 303 East Chicago Ave., Chicago, Ill.)

19–26. Medical Hydrology, 21st intern. cong., Madrid, Spain. (Dr. Francon, 55, rue des Mathurins, Paris 8e, France.)

20–23. American Acad. of Pediatrics, Chicago, Ill. (E. H. Christopherson, 1801 Hinman Ave., Evanston, Ill.)

21. American Soc. of Safety Engineers, annual, Chicago, Ill. (J. B. Johnson, 425 N. Michigan Ave., Chicago 11.)

22–24. Aviation Medicine, 4th annual symp., Santa Monica, Calif. (T. H. Sternberg, UCLA Medical Center, Los Angeles 24, Calif.)

22–26. American Soc. for the Study of Arteriosclerosis, annual, San Francisco, Calif. (O. J. Pollak, P.O. Box 228, Dover, Del.)

23–25. National Soc. of Professional Engineers, San Francisco, Calif. (K. E. Trombley, NSPE, 2029 K St., NE, Washington 6.)

23–25. Rocket Technology and Astronautics, intern., Essen, Germany. (Deutsche Gesellschaft fuer Raketentechnik und Raunfahrt, e.v., Neunsteinerstrasse 19, Stuttgart, Zuffenhausen.)

24–25. International Conference on the Insulin Treatment in Psychiatry, New York, N.Y. (M. Rinkel, 479 Commonwealth Ave., Boston 15, Mass.)

24–25. Taxonomic Consequences of Man's Activities, symp., Mexico, D.F. (H. C. Cutler, Missouri Botanical Garden, St. Louis.)

24–28. American Heart Assoc., San Francisco, Calif. (J. D. Brundage, 44 E. 23 St., New York 10.)

27–28. Plant Physiology, 9th annual research cong., Saskatoon, Saskatchewan, Canada. (D. T. Coupland, Plant Ecology College of Agriculture, Univ. of Saskatchewan, Saskatoon.)

27–29. Radio, Institute of Radio Engineers, fall meeting, Rochester, N.Y. (V. M. Graham, EIA, 11 W. 42 St., N.Y.)

(See issue of 15 August for comprehensive list)

Equipment

The information reported here is obtained from manufacturers and from other sources considered to be reliable. Science does not assume responsibility for the accuracy of the information. A coupon for use in making inquiries concerning the items listed appears on page 434.

■ DELAY RELAYS use transistor circuitry and RC networks to provide delay intervals from 50 msec to several hours. Accuracy of all types is ± 10 percent. Voltage ranges are from 14 to 32 v d-c or 24 to 220 v a-c. Temperature range is – 55° to + 71°C or – 55° to + 125°C. (Jordan Electronics, Dept. 253)

■ TEMPERATURE TRANSDUCER provides response as fast as 10 msec. With an amplifier, response of 1 msec can be achieved. Accuracy is said to be better than 0.1°F. The amplifier provides output of ± 5 v per 100°F with maximum output of ± 20 v available. The unit will withstand accelerations to ± 25 *g* at 0 to 200 cy/sec. (Astra Technical Instrument Corp., Dept. 254)

■ PROPORTIONAL - COUNTER CONVERTER connects to the input of a scaler to convert it to a proportional counter. The instrument incorporates a transistorized amplifier-discriminator. A standard chamber accepts samples up to 2.25 in. in diameter by 7/16 in. Conversion to chambers for larger or smaller samples may be made readily. (Nuclear Measurements Corp., Dept. 260)

■ SUPPORT TOWERS for supporting and positioning antennas, reflectors, and scale-model airframes are constructed entirely of low-dielectric-constant materials above the base unit. The load capacity is 200 lb, and the height is 8 or 16 ft. Positioning drive speed is variable. Two-axis position information is provided. (Scientific Atlanta Inc., Dept. 262)

■ PORTABLE VOLTMETER provides ranges for a-c voltage from 1 mv to 1000 v full scale; d-c voltages from 1 to 1000 v full scale; and resistance from 10 ohm to 10 megohm at half-scale. Over-all accuracy is 3 percent. An electrometer input has an input impedance greater than 10,000 megohm for the 0-to-1-v d-c range. Transistor circuitry is used. (Southwestern Industrial Electronics Co., Dept. 263)

■ TRAINING REACTOR of pool type is designed for use by universities and engineering schools. The reactor, which may be operated at power levels up to 10 kw, is prefabricated except for the concrete shielding, and can be installed in existing buildings. The pool tank is 7 ft in diameter. Standard equipment includes a thermal column, two beam tubes, and

one through tube. A circular walkway permits viewing of the internal workings of the reactor. (Nuclear Products, Dept. 274)

■ FREQUENCY CONVERTER accepts inputs from an impeller-type flow pick-up and converts the input frequency to a proportional d-c voltage. Time constants are selectable from 1 msec to 2 sec. Full-scale frequencies are 500, 2500, and 10,000 cy/sec. Accuracy and stability are said to be better than ±0.1 percent. (Systron Corporation, Dept. 261)

■ HEATING BLOCK is equipped with 13 compartments to accommodate 38-by-300-mm test tubes for aging tests. The temperature is controlled over the range of 100° to 600°F. A temperature controller is provided to prevent override of the master control unit. The block body is made of aluminum and it weighs approximately 169 lb. (Product Packaging Engineering, Dept. 264)

■ OSCILLOGRAPHIC CHART VIEWER provides variable chart-drive speeds from 15 in./min to 100 ft/min. Charts up to 16 in. wide and 200 ft long are accommodated. A direction-reversing switch allows rewinding at any time, and an automatic brake prevents supply-roll overrun upon reduction of speed. A sliding cursor has provision for angular adjustment. (Sanborn Co., Dept. 265)

■ RELAY TESTER permits measurement of pull-in and drop-out voltages, contact make-and-break time, contact bounce, overlap time on make-before-break and break-before-make contacts, and contact resistance. Display is provided on a meter and oscilloscope. Adapters for a variety of relays are available. (Schmeling Electronics, Dept. 267)

■ SAMPLE APPLICATOR for chromatography holds up to seven pipettes, rocking them so that their tips are applied 6, 12, or 18 times per minute to the paper surface. The distance between the points of application is 1 in. Warm air from a blower flows continuously to dry the sample between successive applications. Air flow is regulated by individual valves for each sample. Provision is made for connection of a vacuum line to increase drying efficiency. (Scientific Products, Dept. 276)

■ RESISTANCE CALIBRATOR operating on methods developed at the National Bureau of Standards, permits calibrations up to 100 megohm, with accuracy of ±0.01 percent. The instument consists of 10 precision resistor steps made with encapsulated wire-wound resistors. Each step is adjusted within ±0.01 percent of nominal. (International Resistance Co., Dept. 277)

■ LOW-DIELECTRIC-CONSTANT MATERIAL consists of thin-walled hollow glass spheres ranging in size from 30 to 300 μ in diameter. The bulk appearance resembles sand. Some grades of material are stable at 1500°F. The dielectric constant is 1.15; dissipation factor, 0.002; and bulk density, 10 lb/ft^3. (Emerson & Cuming, Inc., Dept. 268)

■ FORCE TRANSDUCER is operated on the differential-transformer principle, and provides an output of 1.68 v full-scale into a 5000-ohm resistive load with 115 v, 60 cy/sec excitation. The range is 75 or 240 lb. Linearity is ±0.5 percent, with hysteresis less than 0.09 percent. Temperature drift and sensitivity at zero are within 2 percent of full scale per 100°F. (Edcliff Instruments, Dept. 270)

■ THREE-PHASE OSCILLATOR covers frequencies from 1 to 1000 cy/sec in three decade bands. Output is 7 v line-to-line and 4 v line-to-neutral at no load. The phase shift between any two phases is 120±1 deg. Total harmonic distortion is less than 3 percent. Output impedance is approximately 30 kohm line-to-line, or 10 kohm line-to-neutral. Input is 70 w, 115 v a-c 60 cy/sec. (Genisco Inc., Dept. 275)

■ SEGMENTAL RECORDER is a multichannel plotter that features a separate graph on a strip chart of data as a function of time for each input. Up to 192 channels can be plotted; 24-, 32-, 48-, or 96-channel instruments are also available. The individual graphs measure 5½ by 6 in. (Gilmore Industries, Inc., Dept. 280)

■ VIBRATION TESTER permits observation of displacement, velocity, or acceleration by choice of switch setting. Six decade ranges cover full-scale displacements from 0.001 to 100 in. Velocity is indicated from 0.01 to 1000 in./sec full-scale, and acceleration scales range from 0.1 to 1000 *g*. The frequency range is from 5 to 5000 cy/sec. The transducer used is a velocity pick-up. (Ling Electronics, Inc., Dept. 272)

■ THERMOREGULATOR is sensitive to a few thousandths of a degree and is adjustable with an accuracy better than 0.1°C. Adjustment is accomplished by micrometer displacement of a plunger in an exact mass of mercury. Temperature is read on a mechanical counter coupled to the micrometer. Range is set by a second, larger plunger. Counter range is 100°C. (Emil Greiner Co., Dept. 278)

■ OVEN for accelerated-aging tests is equipped with a rotating sample holder positioned so that samples can be suspended and rotated at approximately 1 rev/min. The rotating shelf is 14 in. in diameter and has 37 1-in. openings.

Temperature range is 35° to 180°C. Modification may be made for conventional operation with standard shelves. (Electric Hotpack Co., Inc., Dept. 279)

■ OHMMETER for transistor circuitry features loading of less than 30 mv to 300 ohm. The instrument is direct-reading from 10 mohm to 10 megohm in eight ranges. Accuracy is ± 2 percent. Dimensions are 8½ by 6 by 4½ in. (Electronic Applications, Dept. 281)

■ POTENTIOMETER, SIGNAL SOURCE, and MILLIAMMETER are combined into one instrument designed for testing, calibrating, or servicing controllers and amplifiers. The potentiometer ranges are 0-to-60 and 95-to-105 mv. Voltage taps are provided at 10, 20, 30, 40, 50 and 95 mv, with 0 to 10 mv available from a multiturn slidewire in 2.5 µv increments. An indicating meter is scaled at 0 to 5 ma d-c. (Technique Associates, Inc., Dept 287)

■ THREE-AXIS FLIGHT SIMULATORS duplicate the forces of flight or vessel motion in yaw, pitch, and roll. Speeds up to 50 cy/sec are possible. The units are hydraulically actuated, and the oscillation frequency between axes may be adjusted independently. (J. W. Fecker, Inc., Dept. 282)

■ OSCILLOGRAPH RECORDER writes by the heated-stylus method on rectangular coordinates. Models are available with two to six channels. The frequency response is flat to 70 cy/sec. Eight chart-drive speeds, from 1 to 250 mm/sec, can be selected. The unit is constructed for 19-in. rack mounting. (Edin Co., Inc., Dept. 266)

■ DIGITAL VOLTMETER is a two-module unit consisting of a switch module and a power module. A five-digit display, with automatic ranging and polarity, covers the range from 0.0001 to 999.99 v. Accuracy is 0.01 percent ± 1 digit. Stability is better than ± 0.01 percent. (Electro Instruments Inc., Dept. 269)

■ DROP-COUNTER ACCESSORY extends the range of the manufacturer's fraction collector from 400 to 800 drops per fraction. In addition, the device may be used to count and register the total number of fractions collected, or the total number of drops. Totals are recorded on a six-digit mechanical register. (Research Specialties Co., Dept. 283)

■ TAPE PERFORATOR accepts fixed data from tabulating or edge-punched cards and variable data through its keyboard, and combines the information in its punched-tape output. The equipment is comprised of a separate input console and tape punch, so that a number of remotely located input stations may feed on a single punch. (Taller and Cooper Inc., Dept. 285)

■ AUTOMATIC STOPPERING DEVICE permits sealing of bottles or vials, in which material has been freeze-dried, while they are still in the vacuum chamber. Stoppers are held above the bottle necks in special holders to permit unobstructed drying. At the end of the drying period, the stoppers are forced into place by a pneumatically operated pressure plate. (F. J. Stokes Corp., Dept. 295)

■ CANNULAS for extracorporeal circulation are fabricated of flexible nontoxic vinyl plastic, and may be autoclaved. A double-lumen cannula and an intraperitoneal cannula are available. The latter is transversely ridged to assure continuous return flow, even when it is surrounded by omentum. (Medical Development Corp., Dept. 296)

JOSHUA STERN
National Bureau of Standards

PERSONNEL PLACEMENT

CLASSIFIED: 25¢ per word, minimum charge $4.25. Use of Box Number counts as 10 additional words. Payment in advance is required.

COPY for classified ads must reach SCIENCE 2 weeks before date of issue (Friday of every week).

DISPLAY: Rates listed below—no charge for Box number. Monthly invoices will be sent on a charge account basis — provided that satisfactory credit is established.

Single insertion	$26.00 per inch
13 times in 1 year	24.00 per inch
26 times in 1 year	23.00 per inch
52 times in 1 year	22.00 per inch

For PROOFS on display ads, copy must reach SCIENCE 4 weeks before date of issue (Friday of every week).

Replies to blind ads should be addressed as follows:
Box (give number)
Science
1515 Massachusetts Ave., NW
Washington 5, D.C.

POSITIONS WANTED

Bacteriologist; B.S. (chemistry); M.S. (physiology major); Ph.D. (bacteriology major; mycology minor); 9 years, chief bacteriologist, large teaching hospital; on faculty medical school as instructor. Medical Bureau, Burneice Larson, Director, 900 North Michigan, Chicago. X

Biologist–Zoologist. Ph.D., 1958 fall; 28; desires teaching and/or research position. Available in fall; 7 years' diversified research experience; publications. Box 199, SCIENCE. X

Botanist, Ph.D. Strong in agricultural sciences including agricultural biological chemistry; 7 years' research; 10 years' teaching-administration, Midwest. Seeks relocation in industry or educational institution. Box 198, SCIENCE. X

Botanist–Biologist, Ph.D., 48, 16 years teaching and research experience. Desires relocation. Box 196, SCIENCE. X

Pharmacologist, young Ph.D., several years teaching and research experience. Desires academic or industrial position. Box 201, SCIENCE. X

Ph.D., Microbiology-Biochemistry; 5 years of industrial and academic experience, fermentation processes, chromatography, bioassay, manometric, and radioisotope techniques. Seeks industrial position. Box 179, SCIENCE. 8/8, 22

Plant Physiologist, Ph.D. (1946). Considerable experience in plant nutrition. Desires relocation teaching, research, industrial. Box 197, SCIENCE. X

POSITIONS OPEN

(a) **Biochemist;** M.S., Ph.D., to head section, new diagnostic laboratory to be completed early 1959; 400-bed eastern hospital; to $9000. (b) **Research Associate;** excellent opportunity for recent Ph.D. biochemist, physiologist participate in research program in lipid transport, metabolism; faculty appointment possible; eastern university medical school, affiliated hospital; $6000. (c) **Bacteriologist;** experienced hospital work to head active section, hospital now expanding from 400 beds; to $6000; midwestern university center. (d) **Biochemist;** Ph.D. to supervise two in various research projects in protein isolations and characterizations, transformations, drugs, isolation studies of natural products; to $11,000; East. Woodward Medical Bureau, Ann Woodward, Director, 185 North Wabash, Chicago. X

HARVARD BIOLOGICAL LABORATORIES require **Research Technician and Supervisor** of fully equipped laboratory utilizing radioisotopes in biological investigations. Individual should have a bachelor's or master's degree in chemistry and should be familiar with management and manipulation of radioisotopes. Contact Isotope Committee, Biology Department, Harvard University, Cambridge, Massachusetts. X

Senior Research Pharmacologist. Excellent opportunity exists for young Ph.D. with industrial experience in small, progressive pharmaceutical firm in upstate New York. Have a leading part in exciting and varied research program. Prefer man with cardiovascular and/or gastrointestinal interests. Excellent salary and fringe benefits. Inquiries will be held confidential. Send full information to Box 200, SCIENCE. 8/29, 9/5

POSITIONS OPEN

Physiologist Biochemist. Research associate in lipid metabolism group. Medical school, East Coast. Box 195, SCIENCE. 8/22

Research Assistant with B.S. in chemistry. Some experience in medical research or clinical chemistry desired but not required. Opportunity for work toward advanced degree. Apply Personnel Office, Indiana University Medical Center, 1100 West Michigan Street, Indianapolis, Indiana. 8/22

SCIENCE TEACHERS, LIBRARIANS, ADMINISTRATORS urgently needed for positions in many states and foreign lands. Monthly non-fee placement journal since 1952 gives complete job data, salaries. Members' qualifications and vacancies listed free. 1 issue, $1.00. Yearly (12 issues) membership, $5.00. CRUSADE, SCI., Box 99, Station G, Brooklyn 22 N.Y. ew

POSITIONS OPEN

Experienced Histology Technician, ASCP registered preferred. Supervise histology laboratory in large midwestern teaching hospital, train technicians, opportunity for research. Box 163, SCIENCE. tf

(a) **Physician,** Ph.D., to direct toxological chemical department, large company engaged in industrial research and development. (b) **Biochemist** to head department, 500-bed general hospital; East; $12,000. (c) **Directors of Organic and Biological Research,** Ph.D.'s; new departments, pharmaceutical company; medical center, South. (d) **Industrial Hygienist;** preferably with B.S. degree, chemistry major; 1 year of graduate study in industrial hygiene with basic training in epidemiology and biostatistics, industrial health, environmental physiology and industrial toxicology; foreign appointment. S8-4 Medical Bureau, Burneice Larson, Director, 900 North Michigan Avenue, Chicago. X

USE THIS EASY SELF-MAILER to obtain further information

22 August 1958

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Information Requisition

It's simple: Mark—Clip—Fold—Mail—No stamp required

This coupon is for your convenience—to facilitate your requests for further information about advertised products and items in Equipment.

From:

Name .... **Position** ....

Company ....

Street ....

City .... **Zone** .... **State** ....
(Please print or type)

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No Postage Stamp Necessary If Mailed in the United States

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First Class Permit #12711 New York, N.Y.

Readers' Service

To: SCIENCE MAGAZINE
Room 740
11 West 42 Street
New York 36, New York

Fasten Here Only
Staple, Tape, Glue

The Market Place

BOOKS • SERVICES • SUPPLIES • EQUIPMENT

DISPLAY: Rates listed below—no charge for Box number. Monthly invoices will be sent on a charge account basis — provided that satisfactory credit is established.

Single insertion	$26.00 per inch
13 times in 1 year	24.00 per inch
26 times in 1 year	23.00 per inch
52 times in 1 year	22.00 per inch

For PROOFS on display ads, copy must reach SCIENCE 4 weeks before date of issue (Friday of every week).

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are needed by our library and institutional customers. Please send us lists and description of periodical files you are willing to sell at high market prices. Write Dept. A3S, CANNER'S, Inc. Boston 20, Massachusetts

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22 August 1958

Readers' Service

Information Requisition

Use this easy self-mailer to obtain further information about items or literature from the Equipment section as well as from advertised products.

EQUIPMENT

Circle below desired number corresponding to:

253	254	260	261	262	263	264	265
266	267	268	269	270	272	274	275
276	277	278	279	280	281	282	283
285	287	295	296				

ADVERTISERS IN THIS ISSUE

In list below, check page number of advertiser from whom you would like more information. If more than one item appears in ad, letters (A, B, C) are used to indicate particular items available in order of appearance in advertisement. Where more than one ad appears on page, **"U" indicates upper ad, "L" lower ad, "I" inside ad, "M" middle ad,** and **"O" outside ad.** Advertisements in Personnel Placement and Market Place are not keyed. A multiplicity of items is indicated by *. Readers are requested to specify on this coupon the particular item in which they are interested; otherwise, the request cannot be processed.

☐ 382	☐ 383*	☐ 384*	☐ 386	☐ 424, A
☐ 424, B	☐ 425	☐ 426, A	☐ 426, B	☐ 427
☐ 428	☐ 429	☐ 430, UO	☐ 430, LO	☐ 431, UI
☐ 431, UO*	☐ 431, LI	☐ 431, LO	☐ 432	☐ 436

APPLICATION FOR HOTEL RESERVATIONS

125th AAAS MEETING

Washington, D.C., December 26-31, 1958

The list of hotels and their rates and the reservation coupon below are for your convenience in making your hotel room reservation in Washington. Please send your application, *not* to any hotel directly, but to the AAAS Housing Bureau in Washington and thereby avoid delay and confusion. The experienced Housing Bureau will make assignments promptly; a confirmation will be sent you in two weeks or less.

As in any city, single-bedded rooms at minimum rates may become scarce; double rooms for single occupancy cost more; for a lower rate, share a twin-bedded room with a colleague. Most hotels will place comfortable rollaway beds in rooms or suites at $2.00 to $2.50 per night. Mail your application *now* to secure your first choice of desired accommodations. All requests for reservations must give a definite date and estimated hour of arrival, and also probable date of departure.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Rates for Rooms with Buth

Hotels with an asterisk have sessions in their public rooms. For a list of headquarters of each participating society and section, see page 151, *Science*, July 18.

Hotel	Single	Double Bed	Twin Bed	Suite
*Dupont Plaza	$10.00–11.00	$13.00–14.00	$13.00–14.00	$21.00–27.00
*Sheraton-Park	8.00–12.00	12.00–14.50	11.00–16.00	20.00–60.00
*Shoreham	all 9.00	all 12.00	all 12.00	20.00–50.00
*Statler	all 10.00	all 14.00	all 14.00	24.00–30.00
*Washington	7.00– 8.00	11.00–12.50	11.00–12.50	24.50–45.00
*Willard	10.00–12.50	13.00–17.00	14.00–18.00	25.00–35.00
Roosevelt	7.00– 9.00		10.00–12.00	18.00–24.00
Sheraton-Carlton	12.00–17.00		17.00–21.00	
Windsor Park	all 9.00	all 14.00	all 14.00	13.00–18.00

THIS IS YOUR HOUSING RESERVATION COUPON

AAAS Housing Bureau
1616 K Street, N.W.
Washington 6, D.C.

Date of Application ....

Please reserve the following accommodations for the 125th Meeting of the AAAS in Washington, D.C., Dec. 26–31, 1958:

TYPE OF ACCOMMODATION DESIRED

Single Room .... **Desired Rate** .... **Maximum Rate** ....

Double-Bedded Room .... **Desired Rate** .... **Maximum Rate** .... **Number in party** ....

Twin-Bedded Room .... **Desired Rate** .... **Maximum Rate** ....

Suite .... **Desired Rate** .... **Maximum Rate** .... **Sharing this room will be:**

(Attach list if this space is insufficient. The name and address of each person, including yourself, must be listed.)

....

....

First Choice Hotel .... **Second Choice Hotel** .... **Third Choice Hotel** ....

DATE OF ARRIVAL .... **DEPARTURE DATE** ....

(These must be indicated—add approximate hour, a.m. or p.m.)

NAME ....

(Individual requesting reservation) **(Please print or type)**

ADDRESS ....

(Street) **(City and Zone)** **(State)**

***Mail this now to the Housing Bureau.* Rooms will be assigned and confirmed in order of receipt of reservation.**